NASA

Aeronautical Engineering
A Continuing Bibliography with Indexes

NASA SP-7037(223)
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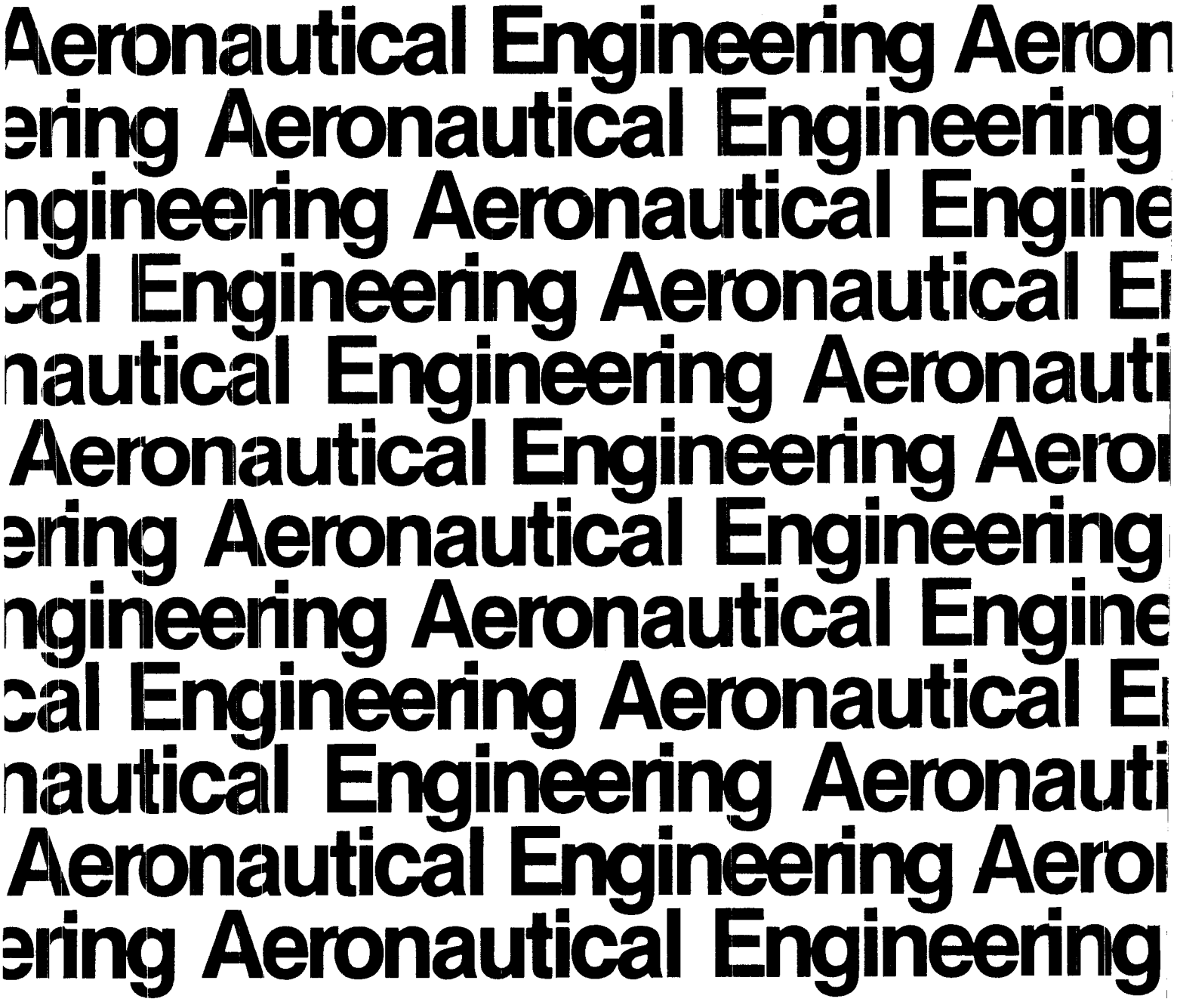
National Aeronautics and Space Administration



NASA SP-7037(223)

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 223)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in January 1988 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

Scientific and Technical Information Division 1988
National Aeronautics and Space Administration
Washington, DC

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INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 423 reports, journal articles and other documents originally announced in January 1988 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cummulative index will be published.

Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

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Category 14 Life Sciences 57
Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and space biology.

Category 15 Mathematical and Computer Sciences 58
Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

Category 16 Physics 61
Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

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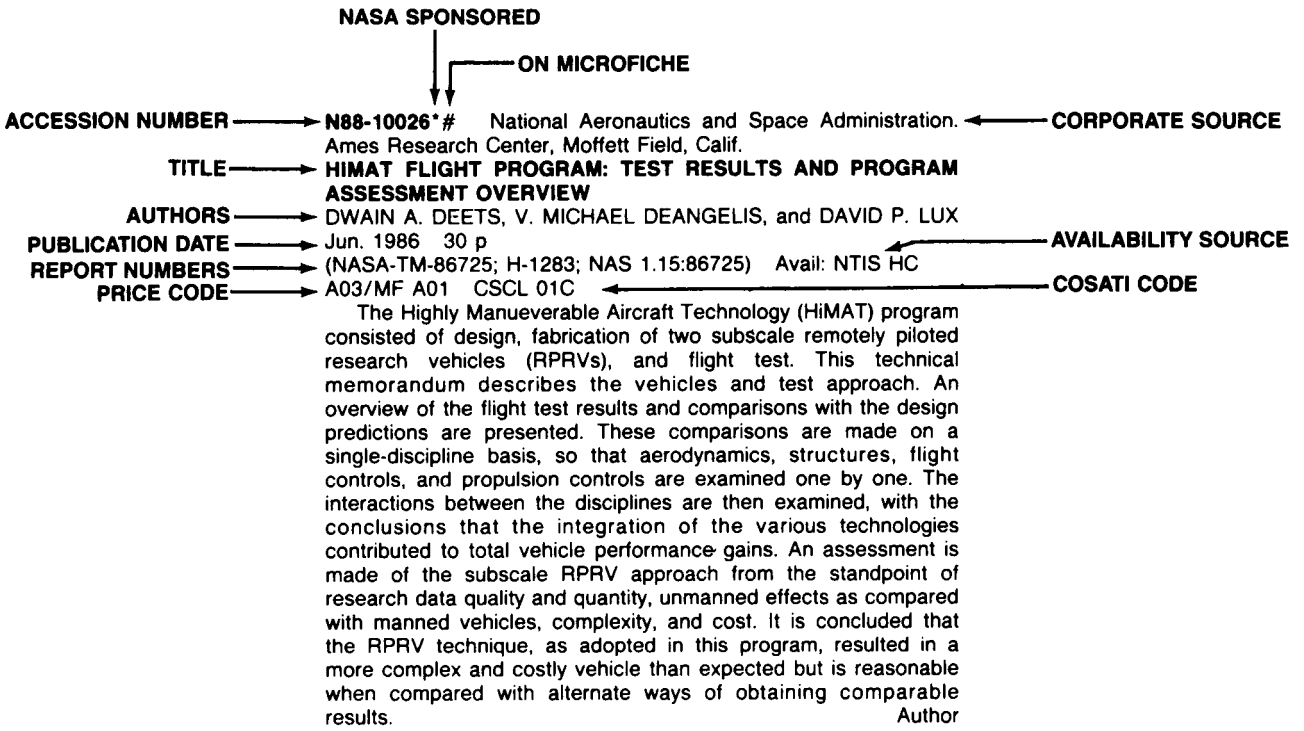
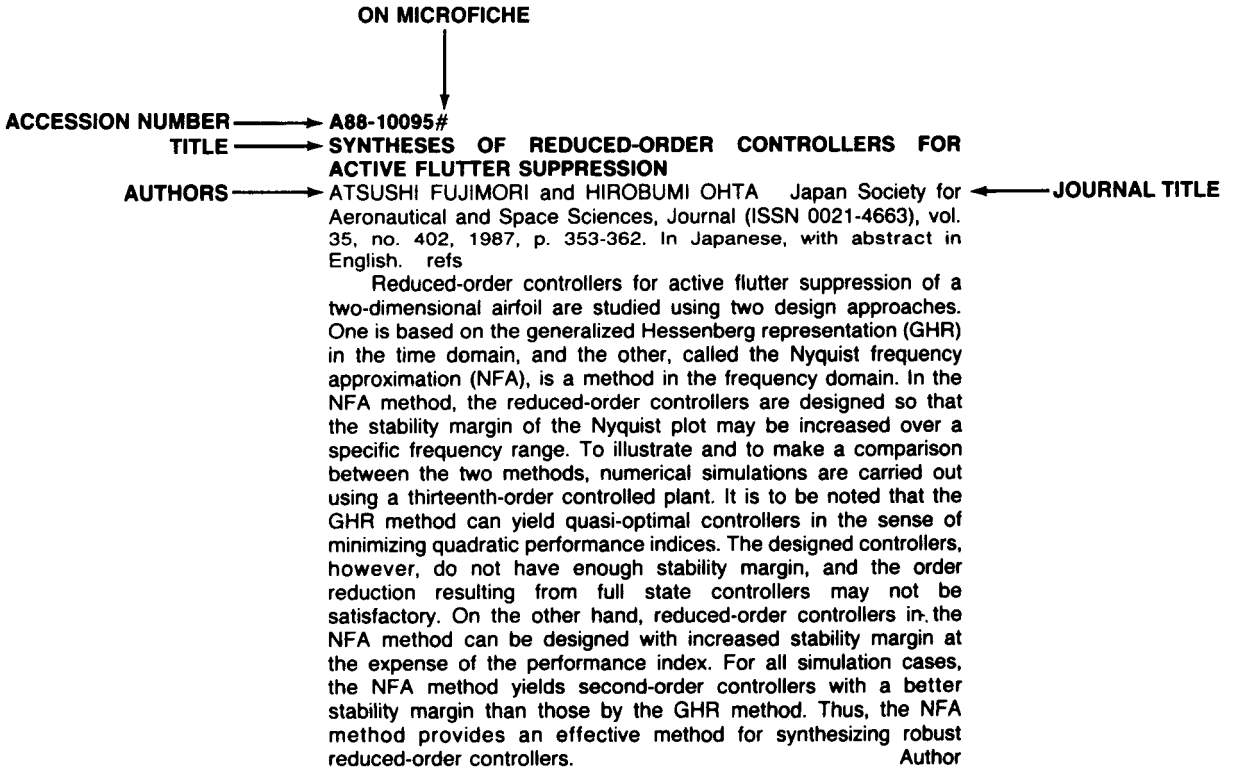
TYPICAL REPORT CITATION AND ABSTRACT



TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 223)

FEBRUARY 1988

01

AERONAUTICS (GENERAL)

A88-10370#
AN ORIENT EXPRESS TO CAPTURE THE MARKET
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 25, Sept. 1987, p. 44-47.

The development of a high-speed aircraft for travel to the Orient is discussed. The economic benefits and commercial applications for an SST are investigated. A number of designs for an SST are presented and analyzed; fuel, safety, and environmental concerns are addressed. The National Aerospace Plane and the X-30 project are examined. I.F.

A88-10657
NEW SOVIET HELICOPTER TECHNOLOGY AND ITS POTENTIAL FOR INDUSTRIAL USE [NEUE SOWIETISCHE HUBSCHRAUBERTECHNIK UND DEREN EINSATZPERSPEKTIVEN IM INDUSTRIEFLUG]
EKKEHARD SCHEER (Interflug Gesellschaft fuer Internationalen Flugverkehr mbH, Berlin, German Democratic Republic) Technisch-oekonomische Information der zivilen Luftfahrt (ISSN 0232-5012), vol. 23, no. 3, 1987, p. 113-116. In German.

The new Soviet helicopters Ka-32 and Mi-26 are described, and the potential spectrum of their uses in the economy of the DDR is considered. The configurations, components, and equipment of these helicopters are described, their particular advantages are mentioned, and the values of their parameters are listed in comparison with those of the Mi-8. The applications of the helicopters in the construction of facilities for energy generation, harbors and coastal facilities, dams, traffic facilities, coal burning plants, and factory construction and reconstruction are discussed. C.D.

A88-10877
ANTI-TANK HELICOPTERS FOR THE RICH AND NOT SO RICH
MARK LAMBERT Interavia (ISSN 0020-5168), vol. 42, Sept. 1987, p. 921-923, 925, 926.

Current designs and characteristic features of antitank helicopters are discussed. The new and improved capabilities and designs of helicopters manufactured by various companies are described. Particular consideration is given to the location of sights for launching TOW and HOT missiles, observation sights, and light antitank helicopters such as the TOW-firing 500MD and the 406 Combat Scout. I.F.

A88-11672
SCHEDULED MAINTENANCE PROGRAM HELPS DELTA MAINTAIN QUALITY
LENA NIRO Materials Evaluation (ISSN 0025-5327), vol. 45, Sept. 1987, p. 1054-1056.

Delta's quality control program and their Technical Operations Center in Atlanta are described. Magnetic particle, fluorescent penetrant, radiographic isotope, high- and low-frequency eddy current, and ultrasonic inspection techniques are used at the center; the advantages of these NDT for detecting surface defects are examined. The use of a preventive (scheduled) maintenance concept to maintain engines and aircraft is discussed. I.F.

A88-13082#
DESIGN AND FABRICATION TRIAL OF A COMPOSITE FLAP STRUCTURE
KENZO TAKASAKI, NOBUKAZU YANAI, ISAO ISHII, and NAOHITO TSUDA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 614-618. In Japanese.

The design and fabrication trial of the composite flap structure of a medium-size commercial transport aircraft are described. An integrated fabrication method involving the combination of steel and rubber components is applied to the construction of the flap structure. The integrated composite structure results in a lightweight and low-cost design as compared with the honeycomb sandwich structure. S.H.

N88-10003# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Abteilung Stabilitaet und Antwort.
THE HISTORY OF AEROELASTICITY RESEARCH IN GERMANY FROM THE BEGINNING UNTIL 1945
PETER BUBLITZ Dec. 1986 319 p In GERMAN; ENGLISH summary Report will also be annouced as translation (ESA-TT-1082)
(DFVLR-MITT-86-25; ISSN-0176-7739; ETN-87-90444) Avail: NTIS HC A14/MF A01; DFVLR, Cologne, West Germany DM 98

Twenty years elapsed between the beginning of powered flight and the comprehension of such aeroelasticity problems as static divergence and flutter. The way in which the first aeroelasticians overcame the difficulties and founded this field of research is described. ESA

N88-10986# Joint Publications Research Service, Arlington, Va.
ENSURING THE SERVICE LIFE OF DESIGNS (EXPERIENCE IN AIRCRAFT CONSTRUCTION)
A. F SELIKHOV and ZHUKOVSKIY *In its* USSR Report: Engineering and Equipment p 1-11 4 May 1987 Transl. into ENGLISH from Mashinovedeniye (Moscow, USSR), no. 5, Sep.-Oct. 1986 p 11-18
Avail: NTIS HC A07/MF A01

The high cost of an aircraft makes it necessary to operate it for 20 to 25 years with ever increasing intensity. Increasing requirements on weight improvement, a significant level of variable loads, long service life and large number of functional and loading cycles results in the fact that the service life of the main load bearing structure of an aircraft is limited, i.e., the design may exhaust its load carrying capacity prematurely. The most frequently encountered and most hazardous due to unexpected causes of possible cessation of operation is structural fatigue due to exhaustion of its load carrying capacity and initial production defects and also damage caused by corrosion and wear. Criteria are enumerated which place limitations on providing the required service life of the design with minimum expenditures of mass. The typical distribution of service life of a design before the first damage in operation is shown. The measures which must be implemented during the very beginning of design, during

manufacture of the aircraft and reliability before beginning of design are briefly discussed. E.R.

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A88-10093#
A NUMERICAL METHOD FOR SUBSONIC UNSTEADY LIFTING SURFACES - BIS. III - SOME ADDITIONAL NUMERICAL RESULTS
MASAMI ICHIKAWA and SHIGENORI ANDO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 402, 1987, p. 339-345. In Japanese, with abstract in English. refs

This paper presents some additional numerical results to previous papers concerning a new computation method for unsteady subsonic lifting surfaces, BIS (box-in-strip). It consists of two parts. One is a comparison between BIS and PCKFM (piecewise continuous kernel-function method); the other is a comparison between BIS and analytical solutions for circular and/or elliptic planform wings in steady incompressible flow. As a result, it is found that PCKFM yields fairly close results to BIS in the case of the rectangular wing with AR = 10 and that correlation between BIS and analytical solutions is much better than in the case of VLM. Author

A88-10094#
THE FLOW VISUALIZATION ON THE ROTARY WING WITH LOW ASPECT RATIO
TADAHARU WATANUKI, MASAYOSHI MATSUZAKA, HIROTOSHI KUBOTA, KOJIRO SUZUKI, KOUICHI SAGAWA et al. Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 402, 1987, p. 346-352. In Japanese, with abstract in English. refs

Flow patterns on a rotary wing with a low aspect ratio of 3.3 are experimentally investigated in the Goettingen type low speed wind tunnel. Single rotation propeller blade with a radius of 0.3 m is used as the model wing for the flow visualization. The flow phenomena on the blade are visualized by means of oil flow, tuft, mini-tuft, and china clay methods and recorded by simultaneous photography. The experimental results clearly show that the mini-tuft method is more suitable for visualizing the flow on the rotary wing. Author

A88-10264
SUPERSONIC FLOW AROUND A SPHERE IN A THERMAL INHOMOGENEITY [SVERKHZVUKOVOE OBTEKANIE SFERY V TEPLOVOI NEODNORODNOSTI]
V. P. GOLOVIZNIN, G. I. MISHIN, IU. L. SEROV, and I. P. IAVOR (AN SSSR, Fiziko-Tekhnicheskii Institut, Leningrad, USSR) Zhurnal Tekhnicheskoi Fiziki (ISSN 0044-4642), vol. 57, July 1987, p. 1433-1435. In Russian. refs

The dynamics of flow around spherical models in air in the presence of a temperature gradient was investigated experimentally at a ballistic testing facility using an instrument with a 15-ns laser source to photograph the flow patterns. Flow patterns are presented for a 20-mm-diameter polished duralumin ball moving at a speed of 1.98 km/s through heated air. It is found that the experimentally observed separation of the head shock wave from the model, Delta/R, differs substantially from the expected values, which is attributed to the nonsteady nature of the flow. V.L.

A88-10300
NECESSARY OPTIMALITY CONDITIONS FOR THREE-DIMENSIONAL BODIES IN SUPERSONIC GAS FLOW [NEOBKHODIMYE USLOVIIA OPTIMAL'NOSTI PROSTRANSTVENNYKH TEL V SVERKHZVUKOVOM POTOKE GAZA]
I. E. MIKHAILOV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 27, July 1987, p. 1111-1114. In Russian.

The problem of determining the optimal shape of a three-dimensional body in supersonic stationary flow of a gas is analyzed under the assumption that all the flow parameters are continuous in the determinacy region of the body. The necessary extreme conditions are derived by using the method of Lagrangian multipliers. The solvability of the conjugate boundary value problem is demonstrated. V.L.

A88-10354*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
NAVIER-STOKES SIMULATIONS OF ROTOR/STATOR INTERACTION USING PATCHED AND OVERLAID GRIDS
MAN MOHAN RAI (NASA, Ames Research Center, Moffett Field, CA) (Computational Fluid Dynamics Conference, 7th, Cincinnati, OH, July 15-17, 1985, Technical Papers, p. 282-298) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 387-396. Previously cited in issue 19, p. 2743, Accession no. A85-40952. refs

A88-10355*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPLICIT MULTIGRID ALGORITHM FOR QUASI-THREE-DIMENSIONAL VISCOUS FLOWS IN TURBOMACHINERY
RODRICK V. CHIMA (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 397-405. Previously cited in issue 07, p. 828, Accession no. A86-19644. refs

A88-10356#
CASCADE VISCOUS FLOW ANALYSIS USING THE NAVIER-STOKES EQUATIONS
ROGER L. DAVIS, RON-HO NI, and JAMES E. CARTER (United Technologies Corp., East Hartford, CT) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 406-414. Research supported by the United Technologies Corp. Previously cited in issue 07, p. 828, Accession no. A86-19645. refs

A88-10357#
CALCULATION OF THREE-DIMENSIONAL VISCOUS FLOWS IN TURBOMACHINERY WITH AN IMPLICIT RELAXATION METHOD
C. HAH (General Electric Co., Schenectady, NY) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 415-422. Previously cited in issue 11, p. 1475, Accession no. A86-26649. refs

A88-10359#
NUMERICAL SOLUTIONS OF SCRAMJET NOZZLE FLOWS
J. A. SCHETZ, F. S. BILLIG, and S. FAVIN (Johns Hopkins University, Laurel, MD) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 440-447. Navy-supported research. Previously cited in issue 18, p. 2610, Accession no. A85-39689. refs

A88-10361*# Science Applications International Corp., Princeton, N.J.
PARABOLIZED NAVIER-STOKES ANALYSIS OF DUCTED SUPERSONIC COMBUSTION PROBLEMS
N. SINHA and S. M. DASH (Science Applications International Corp., Princeton, NJ) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 455-464. Previously cited in issue 07, p. 828, Accession no. A86-19628. refs
(Contract NAS1-16535)

A88-10492* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
PRESSURE FIELD DUE TO DRAG REDUCING OUTER LAYER DEVICES IN TURBULENT BOUNDARY LAYERS
P. R. BANDYOPADHYAY and R. D. WATSON (NASA, Langley Research Center, Hampton, VA) Experiments in Fluids (ISSN 0723-4864), vol. 5, no. 6, 1987, p. 393-400. refs
(Contract NAS1-17296)

The wall static pressure in the vicinity of drag reducing outer layer devices in flat wall turbulent boundary layers has been measured and compared with an inviscid theory. Symmetric and cambered airfoil devices have been examined at small angles of attack and very low chord Reynolds numbers. Airfoil devices impose a sequence of strong favorable and adverse pressure gradients on the boundary layer whose drag is to be reduced. At very small angles of attack (+ or - 2 deg), this pressure field extends up to about three chord lengths downstream of the trailing edge of an airfoil device. Also examined are the pressures on the upper and lower surfaces of a symmetric airfoil device in the freestream and near the wall. The freestream pressure distribution around an airfoil section is altered by the wall proximity. The relevance of lift enhancement caused by wall proximity to drag reduction has been discussed. The pressure distributions on the flat wall beneath the symmetric airfoil devices are predicted well by the inviscid theory. However, the remaining pressure distributions are predicted only qualitatively, presumably because of strong viscous effects.
Author

A88-10498*# California Univ., Berkeley.
EXPERIMENTAL STUDY OF THREE-DIMENSIONAL SEPARATED FLOW SURROUNDING A HEMISPHERE-CYLINDER AT INCIDENCE
ANDREW J. MEADE, JR. (California, University, Berkeley) and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) AIAA, Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 17-19, 1987. 14 p. refs
(AIAA PAPER 87-2492)

Detailed experimental surface pressure coefficient measurements, obtained for a hemisphere-cylinder-flare model in a low supersonic flow (freestream M = 1.2) at various angles of attack (0 deg to 27.5 deg), have been analyzed. The pressure values for each angle of attack were smoothed and checked against their respective oil-flow photographs. The smoothed results were then used to validate a theory which relates the number and type of singular points observed in the oil-flow patterns with local surface-pressure extrema.
Author

A88-10562#
MULTIGRID LOCALIZATION AND MULTIGRID GRID GENERATION FOR THE COMPUTATION OF VORTEX STRUCTURES AND DYNAMICS OF FLOWS IN CAVITIES AND ABOUT AIRFOILS
KARL GUSTAFSON and ROBERT LEBEN (Colorado, University, Boulder) University of Colorado and USAF, Copper Mountain Conference on Multigrid Methods, 3rd, Copper Mountain, CO, Apr. 6-10, 1987, Paper. 15 p. refs

A robust multigrid nested subdomain scheme is applied to a Stokes flow in a unit cavity, and the resolution of 25 corner subvortices is reported. The algorithm is shown to be competitive with a near optimum ADI technique, and it is applied to the infinite airfoil domain problem. Results are then presented for full unsteady Navier-Stokes flow about an NACA 0015 airfoil. The solution procedure consists of using the multigrid solver for the stream function computations, using an ADI scheme to advance the vorticity values in time, and using the multigrid grid generation technique to provide the boundary-fitted coordinates. Good resolution of fine vortical detail and temporal correlation between the experimental and numerical studies are noted.
R.R.

A88-10660
ARBITRARY WINGS OF LOW ASPECT RATIO IN SUBSONIC FLOW
LAZAR DRAGOS (Bucuresti, Universitatea, Bucharest, Rumania) Zeitschrift fuer angewandte Mathematik und Physik (ISSN 0044-2275), vol. 38, July 1987, p. 648-652. refs

The study of the theory of wings of low aspect ratio in incompressible fluids, or compressible subsonic flow, is expanded to include the case of wings of arbitrary planform. Explicit formulas for the calculation of the lift and moment coefficients are derived for wings of arbitrary planform. The fundamental formulas for the lift and moment coefficients are obtained using Green's formula.
R.R.

A88-10983#
NUMERICAL SOLUTION OF STREAM FUNCTION EQUATIONS IN TRANSONIC FLOWS
J. Z. XU, W. Y. NI, and J. Y. DU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p. refs
(ASME PAPER 87-GT-18)

In order to develop the transonic stream function approach, one of the momentum equations is employed to form the principal equation of the stream function which does not contain the terms of the vorticity and the entropy, and the other one is used to calculate the density directly. Since the density is uniquely determined, the problem that the density is a double-valued function of mass flux in the stream function formulation disappears and the entropy increase across the shock is naturally included. The numerical results for the transonic cascade flow show that the shock obtained from the present method is slightly weaker. It is placed further downstream compared to the irrotational stream function calculation, and is closer to the experimental data.
Author

A88-10989#
A SIMPLIFIED METHOD FOR 3-D POTENTIAL FLOW IN TURBOMACHINERY USING VORTEX SHEET BOUNDARY CONDITIONS
H. JIANG, R. CAI, and Y. ZHU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. Research supported by the Chinese Academy of Sciences. refs
(ASME PAPER 87-GT-28)

Within the framework of inviscid flow theory, the character of three-dimensional flow in turbomachinery blade row is discussed. One of the important differences between three-dimensional and two-dimensional flow in turbomachinery is the discontinuity of velocity at the two sides of the trailing edge and across the downstream boundary. The inconsistency of the traditional periodicity conditions for the downstream boundary and of the axisymmetric assumption for the outlet flow with the three-dimensionality of turbomachinery flow is discussed also. For three-dimensional potential flow, the vortex sheet boundary conditions (VSBC) for the downstream boundary and a fully three-dimensional condition for outlet flow are presented. A simplified method is developed by implementation of VSBC on a fixed vortex boundary in order to predict the fully three-dimensional flow in blade passage as well as downstream of blade row. In the present investigation two calculations are carried out. In one calculation the traditional boundary conditions are imposed while in another one, the VSBC are used to demonstrate the capability of the newly developed boundary conditions. The agreement between some calculated results and the theoretical analysis is very good.
Author

A88-10990#
A GENERALIZED NUMERICAL METHOD FOR SOLVING DIRECT INVERSE AND HYBRID PROBLEMS OF BLADE CASCADE FLOW BY USING STREAMLINE-CO-ORDINATE EQUATION
NAI-XING CHEN and FENG-XIAN ZHANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p. refs
(ASME PAPER 87-GT-29)

This paper describes a generalized numerical method for solving direct, inverse and hybrid aerodynamic problems of the blade cascade flow on the stream surface of revolution. The computational method is based on the numerical solution of the streamline coordinate equation by a linear relaxation scheme. Two conventional blade cascades and a tandem blade have been calculated by the present method. Author

A88-10991#
A NEW METHOD OF CALCULATING OPTIMUM VELOCITY DISTRIBUTION ALONG THE BLADE SURFACE ON ARBITRARY STREAM SURFACE OF REVOLUTION IN TURBOMACHINES
ZIXIANG ZOU and DING YUAN (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p. refs
(ASME PAPER 87-GT-30)

A method for calculating the optimum velocity distribution along the blade surface in a two-dimensional incompressible flow is described. This method is based on the theory of boundary layer and the calculation of cascade loss, and it employs the Pontijagin maximum principle and new optimum techniques. The physical model and equations used in the calculation are presented. The procedure involves initially calculating the incompressible steady flow and then extending it to that of the imcompressible flow on an arbitrary surface of revolution. This method is also applicable to the optimum design of two-dimensional compressor blades and long thin revolutionary bodies of axial symmetry. I.F.

A88-11003#
THROUGH-FLOW ANALYSIS OF A MULTI-STAGE COMPRESSOR OPERATING AT NEAR-STALL CONDITIONS
ROBERT P. DRING and DAVID H. JOSLYN (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. Research supported by United Technologies Corp. refs
(Contract NOOO14-85-C-0657)
(ASME PAPER 87-GT-51)

An assessment of through-flow theory was undertaken based on detailed measurements obtained in a large-scale rotating compressor rig. This assessment is focused specifically on the compressor aerodynamics at near-stall conditions since the three-dimensionality of the flow is at its worst under these circumstances, and the assumptions of axisymmetry in the theory are tested far more severely than at design conditions. This assessment demonstrates that a reasonably accurate prediction can be achieved but that major discrepancies can occur near the endwalls where blockage is high. It is also demonstrated that large errors can be incurred when the spanwise description of blockage is inaccurate in its detailed distribution or in its level. Author

A88-11005#
NAVIER-STOKES SOLUTION FOR STEADY TWO-DIMENSIONAL TRANSONIC CASCADE FLOWS
O. KEY KWON (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-54)

A robust, time-marching Navier-Stokes solution procedure based on the explicit hopscotch method is presented for the solution of steady, two-dimensional, transonic turbine cascade flows. The method is applied to the strong conservation form of the unsteady Navier-Stokes equations written in arbitrary curvilinear coordinates. Cascade flow solutions are obtained on an orthogonal, body-conforming 'O' grid with the standard k-epsilon turbulence model. Author

A88-11015#
THE DESIGN OF SHOCK-FREE COMPRESSOR CASCADES INCLUDING VISCOUS BOUNDARY LAYER EFFECTS
AHMED A. HASSAN (Arizona State University, Tempe) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. refs
(ASME PAPER 87-GT-71)

A numerical procedure for the design of shock-free transonic compressor cascades is proposed, taking viscous effects into account and assuming that the boundary layer is fully attached over the blade. A modified inviscid hodograph-based inverse-design algorithm and an inverse boundary layer algorithm (Miner et al., 1971) are iteratively combined. The present method decouples the inviscid subsonic and supersonic regions of the flow, allowing the solution of either an elliptic or hyperbolic-type partial differential equation for the full stream function. The procedure is demonstrated with two examples of shock-free compressor blades. R.R.

A88-11022#
THREE-DIMENSIONAL CALCULATION OF WALL BOUNDARY LAYER FLOWS IN TURBOMACHINES
W. L. LINDSAY (Pratt and Whitney, Quebec, Canada), H. B. CARRICK (Impetrial Chemical Industries, PLC, Middlesbrough, England), and J. H. HORLOCK (Open University, Milton Keynes, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. refs
(ASME PAPER 87-GT-82)

An integral method is used to calculate the three-dimensional turbulent boundary layer development through the blade rows of turbomachines. Simultaneous equations are solved for the growth of streamwise and cross-flow momentum thicknesses, entrainment, the wall shear stress, and the position of maximum cross-flow. The method is shown to predict flows very successfully for lightly loaded compressor blading (the experiments of Horlock, 1963), but less successfully for a highly loaded compressor cascade (the experiments of Lindsay, 1974). In general, the method was found to overestimate the secondary or cross-flow observed in the highly loaded turbine blades of the Carrick (1975) experiments. R.R.

A88-11024#
NUMERICAL SOLUTION OF THREE-DIMENSIONAL TURBULENT FLOWS FOR MODERN GAS TURBINE COMPONENTS
C. HAH (General Electric Co., Schenectady, NY) and J. H. LEYLEK (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-84)

This paper describes the development and assessment of a computer code for three-dimensional compressible turbulent flows in modern gas turbine components. The code is based on a high-order upwinding relaxation scheme with fully conservative control volume. A three-dimensional Reynolds-averaged Navier-Stokes equation is solved with a two-equation turbulence model that has a low Reynolds number modification near the solid wall. The code is applied to the study of compressible flow inside turbine blade rows of modern gas turbines. Measured data and calculations are carefully compared for the production and convection of aerodynamic loss to evaluate the code as an advanced design technique. The predicted aerodynamic performance is further compared with predictions based on current design techniques. Author

A88-11035#
EXPERIMENTAL INVESTIGATIONS OF FLOWS THROUGH A PLANE CASCADE AT LARGE ANGLES OF ATTACK WITH SEPARATIONS
CHUAN-GANG GU, LAI-QIN LUO, and YONG-MIAO MIAO (Xian Jiaotong University, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-96)

Measurements of various parameters in the flows through a cascade at different angles of attack have been performed. The parameters, such as Reynolds stresses, pressure distribution on the blade surface, velocity distribution in the blade passage, and the position of the separation point are measured at a large angle of attack with separations. In addition, the development of the wake is also investigated. A new formula with a second order of accuracy has been developed to analyze the signals of hot wire in flows with high turbulence intensity. The data by a hot wire are compared with those by conventional measurement techniques and by flow visualizations. The results are satisfactory. Author

A88-11043#
SHOCK EMBEDDING DISCONTINUOUS SOLUTION OF ELLIPTIC EQUATION FOR INVERSE PROBLEM OF TRANSONIC S2 FLOW
HONGJI CHEN and CHUNG-HUA WU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-115)

A simple, accurate and reliable computer code, using a conservative form of the stream-function principal equation and embedding the shock relations into the principal equation, has been programmed in order to calculate the transonic flow over the whole S2 surface containing the discontinuity of a passage shock. The program has application to the solution of the three-dimensional transonic flow in a fan or compressor through iterative computation of transonic S1 and S2 flows. The method is used to calculate the S2 flow in a typical transonic rotor. R.R.

A88-11044#
OFF-DESIGN PERFORMANCE OF SUPERSONIC COMPRESSORS WITH FIXED AND VARIABLE GEOMETRY
K.-D. BROICHHAUSEN (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany), H. E. GALLUS, and R. MOENIG (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 14 p. DFG-supported research. refs
(ASME PAPER 87-GT-116)

The blading and flow path geometry of supersonic axial flow compressors employing combinations of characteristic rotors and stators with fixed and variable geometry is investigated. For the supersonic compressor stages presently investigated, it is shown that the three-dimensional passage geometry has an important influence on the off-design performance. Semiempirical models are obtained that numerically describe flow phenomena including the shock-wall, profile-wall, and end-wall boundary layer losses. These models are incorporated into a streamline curvature calculation method in order to provide information regarding the off-design performance. R.R.

A88-11046#
A TRACE GAS TECHNIQUE TO STUDY MIXING IN A TURBINE STAGE
H. D. JOSLYN and R. P. DRING (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-118)

An experimental technique to study mixing in a turbine stage is demonstrated. An axisymmetric, radial temperature profile at the inlet to the first stator of a large-scale, low-speed, single-stage, axial flow turbine model is simulated with a radial trace gas concentration distribution. Mixing or redistribution of the inlet profile by three-dimensional aerodynamic mechanisms is determined from trace gas concentration measurements made in both the stationary and rotating frames of reference at various locations through the turbine. The trace gas concentration contours generated are consistent with flow pitch angle measurements made downstream of the first stator and with surface flow visualization on the rotor airfoil and the hub endwall. It is demonstrated that this trace gas technique is well suited to quantify many aspects of the redistribution and diffusion of an inlet temperature profile as it is convected through a turbine stage. Author

A88-11067#
A DISCUSSION OF THE MEAN S2 STREAM SURFACES APPLIED TO QUASI-THREE-DIMENSIONAL CALCULATION PROGRAMS FOR TURBOMACHINERY DESIGN
XUJIN ZHU and ZHONGQI WANG (Harbin Institute of Technology, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. refs
(ASME PAPER 87-GT-150)

Various definitions of the S2m surfaces applied to quasi-three-dimensional flow calculations in turbomachinery design are clarified, and an extended version of the true S2 stream surface, the pitch-averaged generalized S2 (PAG S2) stream surface, is considered. The governing equations for PAG S2 are derived through introducing nonorthogonal curvilinear coordinates and nonorthogonal velocity components into the pitch-averaged equations. It is demonstrated that PAG S2 is a more universally applicable model for solving the pitch-averaged flow properties of turbine blade passage flow. Neither S2m nor quasi-S2m (an imperfect version of PAG S2) are predicted to give correct mean solutions of the flow-through. R.R.

A88-11071#
NUMERICAL COMPUTATION OF NON-ISENTROPIC POTENTIAL EQUATIONS FOR TRANSONIC CASCADE FLOWS
J. Z. XU, J. Y. DU, and W. Y. NI (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. Research supported by the Chinese Academy of Sciences and Gas Turbine Establishment of China. refs
(ASME PAPER 87-GT-159)

Based on the analysis of the momentum equations and the nonisentropic flow, an 'isentropic density', which is computed according to the isentropic relation and is dependent on the temperature only, is separated from the density. The entropy increase across the shock may be directly calculated from the momentum equations in the divergence form. Iterating it with the classical potential equation may solve the nonisentropic transonic flowfield conveniently. It is seen from the calculations of transonic cascade flow on the surface of revolution that the shock in the nonisentropic calculation is weaker and is located further upstream compared to the classical potential solution, and is in agreement with the experimental results. Author

A88-11072*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
APPLICATION OF ADVANCED COMPUTATIONAL CODES IN THE DESIGN OF AN EXPERIMENT FOR A SUPERSONIC THROUGHFLOW FAN ROTOR
JERRY R. WOOD, JAMES F. SCHMIDT, RONALD J. STEINKE, RODRICK V. CHIMA, and WILLIAM G. KUNIK (NASA, Lewis Research Center, Cleveland, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 15 p. Previously announced in STAR as N87-22630. refs
(ASME PAPER 87-GT-160)

Increased emphasis on sustained supersonic or hypersonic cruise has revived interest in the supersonic throughflow fan as a possible component in advanced propulsion systems. Use of a fan that can operate with a supersonic inlet axial Mach number is attractive from the standpoint of reducing the inlet losses incurred in diffusing the flow from a supersonic flight Mach number to a subsonic one at the fan face. The design of the experiment using advanced computational codes to calculate the components required is described. The rotor was designed using existing turbomachinery design and analysis codes modified to handle fully supersonic axial flow through the rotor. A two-dimensional axisymmetric throughflow design code plus a blade element code were used to generate fan rotor velocity diagrams and blade shapes. A quasi-three-dimensional, thin shear layer Navier-Stokes code was used to assess the performance of the fan rotor blade shapes. The final design was stacked and checked for three-dimensional effects using a three-dimensional Euler code interactively coupled with a two-dimensional boundary layer code. The nozzle design in the expansion region was analyzed with a three-dimensional parabolized viscous code which corroborated the results from the Euler code. A translating supersonic diffuser was designed using these same codes. Author

A88-11077#
CHARACTERIZATION OF SHOCK WAVE END WALL BOUNDARY LAYER INTERACTIONS IN A TRANSONIC COMPRESSOR ROTOR
D. C. RABE, A. J. WENNERSTROM (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH), and W. F. O'BRIEN, JR. (Virginia Polytechnic Institute and State University, Blacksburg) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-166)

The passage shock wave end wall boundary layer interaction in a transonic compressor was investigated with a laser transit anemometer. The transonic compressor used in this investigation was developed by the General Electric Company under contract to the Air Force. The compressor testing was conducted in the Compressor Research Facility at Wright-Patterson Air Force Base, Ohio. Laser measurements were made in two blade passages at seven axial locations from 10 percent of the axial blade chord in front of the leading edge to 30 percent of the axial blade chord into the blade passage. At three of these axial locations, laser traverses were taken at different radial immersions. A total of twenty-seven different locations were traversed circumferentially. The measurements reveal that the end wall boundary layer in this region is separated from the core flow by what appears to be a shear layer where the passage shock wave and all ordered flow seem to end abruptly. Author

A88-11087#
UNIFIED EQUATION OF MOTION (UEM) APPROACH AS APPLIED TO S1 TURBOMACHINERY PROBLEMS
S. ABDALLAH, C. F. SMITH, and M. W. MCBRIDE (Pennsylvania State University, State College) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(Contract N00024-79-C-6043; N00024-85-C-6041)
(ASME PAPER 87-GT-179)

A simple approach is developed for the solution of inviscid blade-to-blade flow in turbomachines. In this approach the equations of motion are combined into a single elliptic second-order partial differential equation of the streamline field; this equation is referred to as the unified equation of motion (UEM). The UEM is used to trace streamline positions. Then, the velocity field is determined by differentiating the stream function field and the use of the computed streamlines. The method was applied to obtain incompressible blade-to-blade flow solutions for S1 turbomachinery, and the results are compared with experimental data and with results of other numerical methods. I.S.

A88-11088#
A MULTI-GRID ALGORITHM FOR 2-D TRANSONIC POTENTIAL CASCADE FLOW
WEI JI, HONGDE JIANG, and RUIXIAN CAI (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-180)

A fast effective multigrid algorithm for calculating two-dimensional transonic cascade flow governed by full-potential equations is presented in this paper. Numerical results obtained show the powerful effect of the method in both accelerating convergence and improving accuracy. In addition, according to the conservation of potential equations, a reasonable treatment for cascade-leading-edge calculations in H-type grids is also presented.

A88-11091#
ANALYSIS OF WINDAGE LOSSES AND VELOCITY DISTRIBUTION FOR A SHROUDED ROTATING DISK
W. GAERTNER (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p.
(ASME PAPER 87-GT-186)

An analysis of experimental results was carried out, establishing a direct correlation between measured velocity profiles and windage losses for a rotating disk inside a shrouded stator as typically found in turbomachinery. The analysis gives information on the regions of the rotating and static parts, which have a dominant effect upon disk windage. Author

A88-11096#
STABILITY OF CONICAL AND CURVED ANNULAR DIFFUSERS FOR MIXED-FLOW COMPRESSORS
A. ABIR (Research Products, Rehovot, Israel) and A. WHITFIELD (Bath, University, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-191)

The internal flow structures for two curved diffusers, a straight conical diffuser, and a straight radial annular diffuser were measured using a two channel hot wire anemometry system and a five hole pitot static tube. The experimental test facility was composed of two axial flow fans that supplied air to the diffusers via a rotating screen arrangement. All the diffusers tested had an inlet width of 56 mm and inlet and discharge radii of 300 mm and 508 mm, respectively. Profiles of the flow throughout the diffusers are analyzed. It is observed that the straight annular diffuser is the least stable and the radial annular diffuser exhibits the best suitability characteristics. It is detected that the flow stability of the two curved diffusers can be improved by reducing the passage width. I.F.

A88-11097#
FLOW INVESTIGATIONS ON SWIRLING COMPRESSIBLE FLOW THROUGH A VANELESS RADIAL DIFFUSER
D. P. AGRAWAL, S. M. YAHYA, and D. N. REDDY (Indian Institute of Technology, New Delhi, India) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-193)

The present study deals with the experimental investigation of swirling compressible flow through a parallel walled vaneless radial diffuser. A swirl generator of vortex-nozzle type is used for supplying swirling compressible flow at the diffuser inlet. The desired flow angles are achieved by adjusting inlet swirl-vane angles from 2.5 to 12.5 deg. The results are presented in terms of performance parameters such as pressure recovery and loss coefficient for various diffuser inlet Mach numbers from 0.3 to 0.8 and flow-angle range from 20 to 35 deg. Author

A88-11101#
MODELLING THE UNSTEADY FLOW IN A TURBINE ROTOR PASSAGE
D. J. DOORLY (University College, London, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 12 p. Research supported by Rolls-Royce, PLC and SERC. refs
(ASME PAPER 87-GT-197)

The effects of the wakes shed by an upstream blade row in forcing the transition of an otherwise laminar rotor blade boundary layer are well recognized. Previous experiments have demonstrated that the forced transition of the laminar boundary layer may greatly influence the surface heat flux. The effect of the wakes on the surface heat flux when the undisturbed boundary layer is already turbulent have been studied using an experimental simulation technique. The results have been analyzed with a view to establishing how well the effects of the wakes can be described by a model which treats only their turbulence content. The effects of wake-passing at a reduced Reynolds number are also reported. Author

A88-11106#
THE BASE PRESSURE AND LOSS OF A FAMILY OF FOUR TURBINE BLADES
L. XU and J. D. DENTON (Cambridge University, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. Research supported by the Royal Aircraft Establishment. refs
(ASME PAPER 87-GT-202)

Measurements of the effect of trailing edge geometry on the base pressure and loss of a family of four turbine cascades are presented. The measurements were made in the transonic range of Mach number from 0.8 to 1.2. It is found that, for blades with typical trailing edge thickness,the trailing edge loss is the major source of profile loss at these speeds and that the base pressure plays a dominant role in determining the loss. For blades with thick trailing edges an accurate prediction of base pressure is crucial to loss prediction. However, it is found that current methods of base pressure prediction are unable to give reliable prediction. Author

A88-11118#
UNSTEADY AERODYNAMIC MEASUREMENTS ON A ROTATING COMPRESSOR BLADE ROW AT LOW MACH NUMBER
L. W. HARDIN, R. O. CARTA, and J. M. VERDON (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 12 p. refs
(Contract F49620-81-C-0088)
(ASME PAPER 87-GT-221)

A heavily instrumented blade row rotating in a realistic compressor model is experimentally investigated to study the unsteady response of a blade row to a prescribed oscillation. Data obtained for steady state conditions agreed with previous pneumatic data at all flow conditions, and agreement was also found with a steady potential flow solution. The quasi-steady response was found to be in fair agreement with the in-phase part of the measured unsteady response for the lowest oscillation frequency, with progressively worse agreement of the in-phase part for higher frequencies. Data acquired under oscillatory conditions agreed with linearized unsteady potential flow predictions over most of the entire chord for low to moderate incidence, and agreement between theory and experiment was better at higher frequencies. R.R.

A88-11121*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
A METHOD FOR CALCULATING TURBULENT BOUNDARY LAYERS AND LOSSES IN THE FLOW CHANNELS OF TURBOMACHINES
LAWRENCE F. SCHUMANN (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. Previously announced in STAR as N87-15944. refs
(ASME PAPER 87-GT-225)

An interactive inviscid core flow-boundary layer method is presented for the calculation of turbomachine channel flows. For this method, a one-dimensional inviscid core flow is assumed. The end-wall and blade surface boundary layers are calculated using an integral entrainment method. The boundary layers are assumed to be collateral and thus are two-dimensional. The boundary layer equations are written in a streamline coordinate system. The streamwise velocity profiles are approximated by power law profiles. Compressibility is accounted for in the streamwise direction but not in the normal direction. Equations are derived for the special cases of conical and two-dimensional rectangular diffusers. For these cases, the assumptions of a one-dimensional core flow and collateral boundary layers are valid. Results using the method are compared with experiment and good quantitative agreement is obtained. Author

A88-11125#
CALCULATION OF A THREE-DIMENSIONAL TURBOMACHINERY ROTOR FLOW WITH A NAVIER-STOKES CODE
MATTHEW J. WARFIELD and B. LAKSHMINARAYANA (Pennsylvania State University, University Park) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. Navy-supported research. refs
(ASME PAPER 87-GT-232)

The paper deals with a numerical solution of the full Navier-Stokes equations governing the flowfield in a turbomachinery rotor. A two-equation turbulence model (k-epsilon) coupled with a vectorial eddy viscosity model based on an algebraic Reynolds stress model is used to account for the anisotropic effects of rotation and three dimensionality. The predicted blade to blade profiles of velocity at various radial locations as well as the streamwise velocity profiles in the blade boundary layer show good agreement with experimental data. Author

A88-11126*# Pratt and Whitney Aircraft, East Hartford, Conn.
INTER AND INTRA BLADE ROW LASER VELOCIMETRY STUDIES OF GAS TURBINE COMPRESSOR FLOWS
M. CARLSON WILLIAMS (Pratt and Whitney, East Hartford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p.
(Contract NAS3-20646)
(ASME PAPER 87-GT-235)

The use of a two-component LDV to study the flow within gas turbine intrablade passages and air flow through multistage compressor rigs is investigated. The LDV, multistage compressor, and the data acquisition system employed in the experiments are described. The velocity magnitude and air angle as a function of rotor position were mapped; modulations in the multistage compressor data resulted in the application of spectral analysis techniques to identify and characterize the periodic fluctuations. It

is noted that the two-component LDV is applicable to the characterization of the aerodynamics of flows. I.F.

A88-11136#
THEORETICAL AND EXPERIMENTAL ANALYSIS OF A COMPRESSOR CASCADE AT SUPERCRITICAL FLOW CONDITIONS
A. WEBER, M. FADEN, H. STARKEN, and V. JAWTUSCH (DFVLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. Research sponsored by the Arbeitsgemeinschaft Industrieller Forschungsvereinigungen. refs
(ASME PAPER 87-GT-256)

Theoretical and experimental results for profile Mach number distribution, loss behavior, and exit flow angle have been compared for a compressed rotor cascade at M1 = 0.85. A two-dimensional finite element method and McNally's (1970) integral boundary layer method are coupled iteratively by adding the displacement thickness to the metal blade contour. The averaged exit flow properties and the total pressure loss coefficient are determined by using the conservation laws. Good agreement is found between experimental and theoretical results regarding profile Mach number distribution over the whole incidence range. It is suggested that discrepancies for losses at negative incidences can be reduced by more accurately accounting for the shock boundary layer interaction, the shock induced separation, and the strength of the shock wave. R.R.

A88-11176
AERODYNAMICS AT LOW REYNOLDS NUMBERS RE GREATER THAN 10 TO THE 4TH AND LESS THAN 10 TO THE 6TH; PROCEEDINGS OF THE INTERNATIONAL CONFERENCE, LONDON, ENGLAND, OCT. 15-18, 1986. VOLUMES 1, 2, & 3
Conference supported by the U.S. Navy. London, Royal Aeronautical Society, 1986, p. Vol. 1, 280 p.; vol. 2, 287 p.; vol. 3, 390 p . For individual items see A88-11177 to A88-11210.

Various papers on aerodynamics at low Reynolds numbers are presented. The topics addressed include: massive laminar separation and lift anomalies in the subcritical Re range, smoke-wire study of low Re flow over a NASA LRN(1)-1007 airfoil section, transition and separation control on a low-Re number airfoil, recent developments in boundary layer computation and in the calculation of flow over low-Re airfoils, determination of the 2-D characteristics of airfoils at low Re, recent wind tunnel experiments at low Re, low-Re aerodynamics research at NASA Langley Research Center, use of wind tunnel data in the design of radio-controlled contest model sailplanes, and wind tunnel testing of small-scale pressure-tapped model propellers. Also discussed are: prediction of a microlight biplane's airfoil performance using a computer model, low-Re airfoil family for horizontal axis wind turbines, experimental investigation of the aerodynamics of the hang glider, aerodynamics of gliding parachutes, development of an efficient oceanographic fairing for operation at Re = 250,000, selection of airfoil sections for use in man-powered aircraft, and aerodynamic force coefficients determined from a vertical axis wind turbine simulator. C.D.

A88-11177
AERODYNAMICS AT LOW REYNOLDS NUMBERS - A REVIEW OF THEORETICAL AND EXPERIMENTAL RESEARCH AT DELFT UNIVERSITY OF TECHNOLOGY
J. L. VAN INGEN and L. M. M. BOERMANS (Delft, Technische Hogeschool, Netherlands) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 1.1-1.41. DFVLR-supported research. refs

This paper gives a review of research on low Reynolds number aerodynamics. Typical for this Reynolds number range is the occurrence of significant effects of laminar separation bubbles. Results of flow visualization studies are used to define an empirical relation for the angle gamma at which the separation streamline leaves the wall. The e exp n transition prediction method is extended to separated flows. It is shown that a simple bursting criterion is provided by Stratfords limiting pressure distribution for a zero skin friction turbulent boundary layer. A universal description of the laminar part of the bubble is proposed, resulting in a simple bubble prediction method. The effect of tripping devices to decrease the adverse effect of the bubble on drag is discussed. The final chapter presents some results of low Reynolds number airfoil designs and tests. Author

A88-11178
ON MASSIVE LAMINAR SEPARATION AND LIFT ANOMALIES IN SUBCRITICAL RE-RANGE
H. K. CHENG, ED. (Southern California, University, Los Angeles, CA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 2.1-2.41. Navy-supported research. refs

Lift anomalies arising from massive laminar separation are studied in the framework of steady-state solutions to the problem of a body-scale flow, with the 'triple-deck' as a key element. Existing studies by this approach are summarized; more complete results, representing multiple steady states of the open- and closed-wake models, provide an analytical basis for explaining lift hysteresis, symmetry breaking, and other forms of lift anomalies in a subcritical flow. The importance of time-accurate analyses in providing the data base for the assessment of these bifurcating steady states is discussed. Also noted is the relevance of the development from the triple-deck theory of the marginal stall to an explanation of the anomalous L/D increase of certain airfoils just before stall at a high subcritical Re. Author

A88-11179
A SIMPLE METHOD FOR THE PREDICTION OF SEPARATION BUBBLE FORMATION ON AEROFOILS AT LOW REYNOLDS NUMBER
F. N. COTON and R. A. MCD. GALBRAITH (Glasgow, University, Scotland) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 3.1-3.17. refs

An aerofoil analysis code is described and its application to separated laminar flows discussed. A technique is developed for the prediction of the onset of long separation bubble formation on an aerofoil, from the separated laminar flow condition. Comparison with experimentally obtained data for one aerofoil is made and good agreement is obtained. Comments on the general applicability of the method are made, and its limitations discussed. Author

A88-11180
A THEORETICAL STUDY OF SPANWISE-PERIODIC 3-D DISTURBANCES IN THE WAKE OF A SLIGHTLY STALLED WING AT LOW REYNOLDS NUMBERS
G. R. INGER (Iowa State University of Science and Technology, Ames) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 4.1-4.21. refs
(Contract AF-AFOSR-85-0357)

For a slightly aft-stalling, large aspect-ratio wing in laminar flow, the formation and properties of spanwise-periodic, three-dimensional, small disturbances within the boundary layer along the otherwise straight separation line in a nominally two-dimensional flow is investigated. The physical mechanism, streamline inclination at separation, local streamline curvature above separation, local instability criterion at separation, and eigenvalue problem for the neutrally stable disturbances are analyzed for streamwise vortex formation at separation. The

implications of the results for the near-wake structure and momentum defect are considered. C.D.

A88-11181* Virginia Univ., Charlottesville.
A SMOKE-WIRE STUDY OF LOW REYNOLDS NUMBER FLOW OVER A NASA LRN(1) - 1007 AIRFOIL SECTION
S. S. FISHER (Virginia, University, Charlottesville) and J. D. ABBITT IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 5.1-5.28. refs

Smoke-filament visualization photographs are presented for two-dimensional flow over a NASA LRN(1) - 1007 airfoil section designed specifically for high-efficiency operation at low chord Reynolds numbers. Results are included for chord Reynolds numbers of 60,000, 100,000, and 220,000 and for angles of attack ranging from 0 to 16 degrees. Two kinds of laminar separation bubble are found to develop in the flow over the airfoil. The sites and characteristics of formation of these bubbles are described, and their dimensional properties are estimated. The transition-to-turbulence Reynolds numbers, surface pressure coefficient distributions, and lift coefficents deduced from the measured coefficients are compared with those obtained by other authors. C.D.

A88-11182
AN ANALYSIS OF UNSTEADY, TWO-DIMENSIONAL SEPARATION BUBBLES
HELEN REED (Arizona State University, Tempe) and LAURA PAULEY (Stanford University, CA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 6.1-6.18. refs
(Contract N00014-84-K-0232; N00014-86-K-0066)

The following is a report on the ongoing analysis of unsteady, two-dimensional separation bubbles by triple-deck theory. Velocity profiles are presented for various freestream pressure gradients expected in low-Reynolds-number flight. The companion experiments for predictive-model verification are described. Author

A88-11183
LOW REYNOLDS NUMBER AIRFOIL DESIGN AT THE DOUGLAS AIRCRAFT COMPANY
R. H. LIEBECK (Douglas Aircraft Co., Long Beach, CA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 7.1-7.24. refs

Development of low Reynolds number airfoil technology at the Douglas Aircraft Company over the past 15 years is described. This includes an explanation of some fluid mechanical problems, such as control of the omnipresent laminar separation bubble, which are unique to the low Reynolds number flight regime. Performance trades between design C(l), C(m), C(l)max, and t/c are discussed and illustrated with wind tunnel results from several example airfoils. Recommendations for future airfoil design and testing are offered. Author

A88-11184
BOUNDARY LAYER AND PERFORMANCE CHARACTERISTICS FROM WIND TUNNEL TESTS OF A LOW REYNOLDS NUMBER LIEBECK AIRFOIL
P. LEBLANCK, R. H. LIEBECK, and R. BLACKWELDER (Southern California, University, Los Angeles, CA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 8.1-8.19. refs
(Contract N00014-84-K-0500)

Experimental data is presented for an investigation of both global performance parameters and more detailed boundary layer flowfield characteristics of a Liebeck LA2573A airfoil designed for use at low Reynolds numbers. Hot-wire mean velocity and turbulent intensity profiles illustrate the development of a laminar separation bubble through transition and reattachment, while boundary layer spectra highlight the progression of instabilities toward transition. Increases in the free stream turbulence level promote earlier transition and a smaller separation bubble. Author

A88-11185
ATMOSPHERIC TURBULENCE AND GUST ON THE PERFORMANCE OF A WORTMANN FX 63-137 WING
H.-T. LIU (Flow Research Co., Kent, WA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 9.1-9.25. refs
(Contract N00014-85-C-0214)

The unsteady effects of turbulence and gust on the performance of a full-scale Wortmann FX 63-137 wing with a 3.66 m span and 0.61 m chord are experimentally studied. The chord Reynolds number ranges from 80,000 to 450,000 and the turbulence intensity from 8 to over 40 percent. The spectra of the wind components show that the reduced frequencies experienced by the wing may be up to 0.1 or higher, indicating that unsteady effects are important. The instantaneous angle of attack of the wing is mainly governed by variations in the vertical wind component. Thus, the wing experiences mainly a plunging rather than a pitching motion, together with sweeping and longitudinal oscillations due to the unsteady, three-dimensional wind field. Significant lift overshoot is observed in the full-scale data, resulting in a significant increase in the C(L)max and in the stall angle. A twofold reduction in C(D)min is also observed. C.D.

A88-11186* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
TRANSITION AND SEPARATION CONTROL ON A LOW-REYNOLDS NUMBER AIRFOIL
S. M. MANGALAM, A. BAR-SEVER (AS&M, Inc., Hampton, VA), K. B. M. Q. ZAMAN (NASA, Lewis Research Center, Cleveland, OH), and W. D. HARVEY (NASA, Langley Research Center, Hampton, VA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 10.1-10.19. refs
(Contract NAS1-17670; NAS1-17683; NAS1-18235)

The major problem associated with the aerodynamic performance of airfoils at low Reynolds numbers is the presence of extensive laminar boundary-layer separation resulting in a large increase in presssure drag and a decrease in lift. The rapid deterioration in airfoil characteristics can be largely eliminated by artificially controlling the flow through the introduction of suitable disturbances in the boundary layer such that transition occurs ahead of the anticipated laminar separation. This paper presents the results of wind-tunnel tests conducted on a 10-cm model of LRN (1)-1007 airfoil with passive (roughness trips) and active (acoustic excitation) controls to trigger transition and suppress separation. Significant improvements in the aerodynamic characteristics of the airfoil were observed. Results of this study for a chord Reynolds

number range of 40,000 to 250,000 are presented in this paper.
Author

A88-11187
CONTROL SURFACE EFFECTS ON THE LOW REYNOLDS NUMBER BEHAVIOR OF THE WORTMANN FX 63-137
J. F. MARCHMAN, III and V. SUMANTRAN (Virginia Polytechnic Institute and State University, Blacksburg) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 11.1-11.14. refs
(Contract N00014-84-K-0093)

The effects of control-surface deflections on the flow around and on the aerodynamic performance of two Wortmann FX 63-137 wings were studied experimentally in the Virginia Tech Stability Wind Tunnel. Tests were conducted at Reynolds numbers from 70,000 to 300,000 on wings of aspect ratio four and nine with various arrangements of 30 percent chord trailing edge control surfaces deflected between angles of + or - 40 degrees and used as both plain flaps and ailerons. Positive flap deflection yielded fairly conventional flap behavior and caused no noticeable changes in basic low Reynolds number flow patterns. Negative deflections cause large changes in the flow and marked deterioration of lift and drag. Negative deflections may alter the basic nature of stall at a given Reynolds number. Aileron behavior was predictable and resembles that expected at higher Reynolds numbers. The results include force, moment, and pressure distribution data.
Author

A88-11188
RECENT DEVELOPMENTS IN BOUNDARY LAYER COMPUTATION
R. EPPLER (Stuttgart, Universitaet, Federal Republic of Germany) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 12.1-12.18.

The most important and difficult part of the boundary layer computation for low Reynolds numbers is to simulate the laminar separation bubble. A very simple and successfully applied model is a bubble analogue which can be evaluated from a conventional computational method based upon the integral momentum and energy equation. Recently, it turned out that this model was not sharp enough and yielded a too short analogy of the bubble. Modifications are discussed which improve the model. Comparisons with experiments are presented. Author

A88-11189
ON SOME UNSTEADY AERODYNAMICS CHARACTERISTICS OF AN NACA 0012 AT REYNOLDS NUMBERS OF 125,000 AND 400,000
M. FLETCHER and E. COVERT (MIT, Cambridge, MA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 13.1-13.33. refs

The unsteady pressures and boundary layers of an NACA 0012 airfoil at Reynolds numbers of 125,000, 400,000, 700,000, and 1 million and reduced frequencies of 0.5, 1.0, 2.0, and 6.4 are examined. The flow quality of the facility is discussed, and the effects of reduced frequency on the pressure distribution and of Reynolds number are considered. The Law of the Wall and Law of the Wake relations are addressed for unsteady boundary layers. C.D.

A88-11190* Notre Dame Univ., Ind.
LOW REYNOLDS NUMBER WIND TUNNEL MEASUREMENTS - THE IMPORTANCE OF BEING EARNEST
THOMAS J. MUELLER, STEPHEN M. BATILL, MICHAEL BRENDEL, MARK L. PERRY, DIANE R. BLOCH (Notre Dame, University, IN) et al. IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 14.1-14.18. Research supported by the University of Notre Dame. refs
(Contract NSG-1419; N00014-83-K-0239)

A method for obtaining two-dimensional aerodynamic force coefficients at low Reynolds numbers using a three-component external platform balance is presented. Regardless of method, however, the importance of understanding the possible influence of the test facility and instrumentation on the final results cannot be overstated. There is an uncertainty in the ability of the facility to simulate a two-dimensional flow environment due to the confinement effect of the wind tunnel and the method used to mount the airfoil. Additionally, the ability of the instrumentation to accurately measure forces and pressures has an associated uncertainty. This paper focuses on efforts taken to understand the errors introduced by the techniques and apparatus used at the University of Notre Dame, and, the importance of making an earnest estimate of the uncertainty. Although quantitative estimates of facility induced errors are difficult to obtain, the uncertainty in measured results can be handled in a straightforward manner and provide the experimentalist, and others, with a basis to evaluate experimental results. Author

A88-11191
RECENT DEVELOPMENTS IN THE CALCULATION OF FLOW OVER LOW REYNOLDS-NUMBER AIRFOILS
TUNCER CEBECI, G. S. WANG, K. C. CHANG, and J. CHOI (California State University, Long Beach) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 15.1-15.13. refs
(Contract N00014-85-K-0346)

A method developed previously for high Reynolds number flows is extended and used to calculate the flow over low Reynolds-number airfoils and to obtain results which can be compared with measurements. It is based on the interaction of solutions of inviscid and boundary-layer equations and involves the flow around the airfoil and its wake. The inviscid equations are solved by a conformal-mapping procedure and the boundary-layer equations by an inverse finite-difference procedure with an interaction formula. The emphasis of the paper is on transition in low Reynolds number flows with separation and on the influence of the wake which is known to be important with high angles of attack and high Reynolds numbers. A correlation formula based on linear stability theory is developed and used to calculate transition. The results show that the accurate prediction of transition is important and is satisfied by the present formula. They also demonstrate the need to include the wake in low Reynolds-number flow calculations for all angles of attack.
Author

A88-11192
ON THE DETERMINATION OF THE 2-D CHARACTERISTICS OF AEROFOILS AT LOW REYNOLDS NUMBERS
D. I. A. POLL and A. MANSOOR (Cranfield Institute of Technology, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 16.1-16.16. refs

This paper describes an experimental investigation of the aerodynamic characteristics of the NACA 23012 aerofoil in the Reynolds number range 200,000 to 400,000. Tests were conducted using a variable aspect ratio rig in an open-jet wind tunnel. Lift

forces and pitching moments were deduced by integrating surface pressures, and the drag force was obtained by the wake traverse technique. Special attention was paid to the attainment of infinite aspect ratio - or two-dimensional - flow conditions. Preliminary data are compared with existing information covering the Reynolds number range 700,000 to 9 million. Guidelines for the investigation of two-dimensional aerofoil characteristics in open-jet wind tunnels are proposed. Author

A88-11193
RECENT WIND TUNNEL EXPERIMENTS AT LOW REYNOLDS NUMBERS
DIETER ALTHAUS (Stuttgart, Universitaet, Federal Republic of Germany) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 18.1-18.42. refs

Work conducted on low Reynolds number aerodynamics at the Institute for Aerodynamics and Gasdynamics of the University of Stuttgart is reviewed. The general characteristics of testing in the laminar wind tunnel and model wind tunnel at the facility are described. Tests to determine the effects of hysteresis in lift and drag on the FX 63-137, the Lissaman 7669, the Miley 06-13-128, the AH 79-100 B, and the E 214 airfoils are reviewed. It is concluded that hysteresis at low Reynolds numbers is caused by two different mechanisms: at low angles of attack by transition from subcritical to supercritical state of flow and vice-versa, and at high angles of attack by bursting and reattachment of a laminar separation bubble near the leading edge. C.D.

A88-11194* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
LOW-REYNOLDS NUMBER AERODYNAMICS RESEARCH AT NASA LANGLEY RESEARCH CENTER
WILLIAM D. HARVEY (NASA, Langley Research Center, Hampton, VA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 19.1-19.49. refs

The present status of various types of low-Reynolds number aerodynamics research being conducted at the Fluid Dynamics Branch of NASA Langley Research Center is reviewed. The facilities, testing techniques, airfoil design, and experimental verification are addressed, and ongoing studies of laminar separation bubbles, boundary layer stability and transition control, and low-Reynolds number juncture flow are discussed. The possibility of improving vehicle characteristics at low Reynolds numbers and the general trends of the most promising research in these areas are examined. C.D.

A88-11197
THE CALCULATION OF FLOW ABOUT AEROFOILS AT LOW REYNOLDS NUMBER WITH APPLICATION TO REMOTELY PILOTED VEHICLES
B. R. WILLIAMS (Royal Aircraft Establishment, Farnborough, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 22.1-22.49. refs

Experimental results from tests on five airfoils (NACA 4412, NACA 64/3/-418, Gottingen 797, Wortmann FX63-137, and GA/W/-2) are compared with calculations by a viscous-inviscid interaction method. Particular attention is paid to flows at a Reynolds number just below one million. It is shown that the theoretical method gives adequate predictions of the variation of lift and drag, and movement of the position of transition from laminar to a turbulent boundary layer with increasing incidence. The paper concludes with some suggestions for improving the viscous-inviscid interaction method, which would allow calculations at even lower Reynolds numbers. Author

A88-11198
PREDICTION OF A MICROLIGHT BIPLANE'S AEROFOIL PERFORMANCE USING A COMPUTER MODEL
P. G. WALTON (Sunderland Polytechnic, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 23.1-23.33. refs

A project to design the wing section of the MBA Tiger Cub 440 microlight biplane is discussed. The basic airfoil found on the standard aircraft is evaluated, a high-lift device is studied, and the effect of variable airfoil geometry due to unstable properties of the fabric used to cover the wings is examined. Three approaches are used in the study: semiinverse viscous flow predictions, wind tunnel experiments, and flight tests. The usefulness of these methods is compared. C.D.

A88-11200
AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMICS OF THE HANG GLIDER
M. V. COOK and E. A. KILKENNY (Cranfield Institute of Technology, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 25.1-25.20. SERC-supported research. refs

A88-11201
THE AERODYNAMICS OF GLIDING PARACHUTES
J. S. LINGARD (G.Q. Defence Equipment, Ltd., Parachute Div., Woking, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 26.1-26.41. refs

The development of gliding parachutes is reviewed, and it is shown how simple aerodynamic theory explains the performance of the most successful gliding decelerator to date, the ram air parachute. The use of the same theory to identify the features limiting that performance, thus leading to the development of a parachute giving gliding efficiency considerably better than any previous nonrigid device, is shown. C.D.

A88-11202
THE EFFECT OF GRIT ROUGHNESS ON THE PERFORMANCE OF THE WORTMANN FX63-137 AIRFOIL AT A CHORD REYNOLDS NUMBER OF 100,000
ARTHUR F. HUBER, II and THOMAS J. MUELLER (Notre Dame, University, IN) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 28.1-28.16. Research supported by the University of Notre Dame. refs (Contract N00014-83-K-0239)

An experimental investigation was conducted on the performance and boundary-layer characteristics of the Wortmann FX63-137 airfoil with and without distributed grit roughness. Data were obtained through use of a three-component strain gage force balance and static pressure measuring equipment at a test chord Reynolds number of Rc = 100,000. Emphasis was placed on determining the effect of grit placement and size on performance parameters. Prediction of the transition location by the criterion due to Klebanoff et al. (1955) was found to have limited application. In most cases airfoil performance was degraded, but in some instances minimum drag was reduced and maximum lift to drag ratio increased. Author

A88-11203
PRELIMINARY MEASUREMENTS OF THE FLIGHT PERFORMANCE OF AN RPV COMPARED WITH WIND TUNNEL AND CFD ESTIMATES
D. J. DYER and J. L. STOLLERY (Cranfield Institute of Technology, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 29.1-29.14. Research supported by the Ministry of Defence. refs

The results of wind tunnel tests on replacement wings for the X-RAE 1 experimental RPV are reported and discussed. The sections used were the Goettingen 797, the Wortmann FX 63-137, and the NACA 64(3)-418. Tests over the Reynolds number range from 300,000 to 1 million showed that the 797 and the Wortmann wing sections have good performance characteristics. Comparisons with the computational model of Williams (1984) revealed that the model shows considerable promise of coping with laminar separation, transition, turbulent reattachment, and turbulent separation likely to occur in the above Re range. The addition of roughness degraded the performance of all three sections, particularly the 797. Full-scale tests on a complete RPV model clearly showed the advantages of fitting a wing of Wortmann rather than flat-bottomed section. C.D.

A88-11204
AERODYNAMICS OF UNMANNED AIRCRAFT AT FULL-SCALE IN THE RAE 24FT WIND-TUNNEL
W. J. G. TREBBLE (Royal Aircraft Establishment, Farnborough, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 30.1-30.29. refs

Wind-tunnel tests have been made on full-scale models of the X-RAE 1 and X-RAE 2 unmanned aircraft in the RAE 24 ft wind tunnel over a Reynolds number range (0.5-1.2) x 10 to the 6th. The results show that substantial increases in lifting capability could be achieved by choosing a wing section (Wortmann FX63-137) more appropriate to the range of Reynolds number associated with the required airspeed range from 20 m/s to 50 m/s. The UMA stalls from the root trailing-edge so the 1 deg washout provided appears to be unnecessary. The UMAs have adequate stability margins and both have powerful nose-down moments at the stall. Some increase in lift/drag ratio occurs as the Reynolds number is raised. Author

A88-11205
LOW ALTITUDE/AIRSPEED UNMANNED RESEARCH AIRCRAFT (LAURA) PRELIMINARY DEVELOPMENT
RICHARD J. FOCH (U.S. Navy, Naval Research Laboratory, Washington, DC) and RANDALL E. WYATT (U.S. Navy, Office of Naval Research, Arlington, VA) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 31.1-31.29. Navy-supported research. refs

The stringent constraints on the design of the Low Altitude/Airspeed Unmanned Research Aircraft (LAURA) requires the development of both highly efficient low Reynolds number airfoils and advanced airframes/systems. The aerodynamic development of multiple planform configurations are presented. Preliminary designs for aft tail twin boom, span-hinged conventional wing/tail, unswept tandem wing, and tip-joined swept tandem wing configurations are provided. Select wind tunnel test results for each configuration are also included. C.D.

A88-11206
THE PERFORMANCE OF MODEL AIRCRAFT USING FLOW INVIGORATORS, GLIDING IN THE CRITICAL RANGE OF REYNOLDS NUMBER
MARTYN S. PRESSNELL (Hatfield Polytechnic, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 32.1-32.32. refs

The behavior of the Benedek 6356b airfoil, fitted with a leading-edge turbulator and various combinations of invigorators and operating in the critical range of Reynolds number, was investigated experimentally. The effects observed are attributed to the formation, control, and eventual collapse of vortex bubble flow in the boundary layer. This information is used to predict the gliding performance of free-flight competition models conforming to the FAI International classes F1A, F1B and for Coupe D'Hiver, and A1 glider classes. It is shown that significant advantage may be gained by operating models with an appropriate aspect ratio. Author

A88-11207
SELECTION OF AEROFOIL SECTIONS FOR USE IN MAN-POWERED AIRCRAFT
KEITH SHERWIN (Nanyang Technological Institute, Singapore) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 33.1-33.8. refs

The availability and choice of airfoil sections for use in the design of man-powered aircraft are studied. In particular, the data available on the Lissaman 7769 section are reviewed and comparison is made with the equivalent aerodynamic performance of the Wortmann FX 63-137, FX 76-MP-120, and FX 76-MP-160 sections using two criteria: power/weight ratio, which is suitable for man-powered aircraft used for training, and lift/drag ratio, which is suitable for man-powered aircraft for speed/sports competition. The FX 63-137 is found to have no performance advantage; the 7769 and the FX 76-MP-120 have excellent performance. The latter can operate at higher C(L) values, resulting in a smaller wing area for a given speed and hence a more compact aircraft. On the other hand, the 7769 allows for easier construction due to its simple shape and its tolerance for imperfections. C.D.

A88-11208
WIND-TUNNEL TEST RESULTS OF EPPLER 387 AEROFOILS AND COMPARISONS WITH FLIGHT TEST AND COMPUTATION
T. J. PATRICK (University College, London, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 34.1-34.8. refs

Wind tunnel test results on the Eppler Profile 387 are compared with each other and with computational results. Free gliding characteristics of one test model are measured over a Reynolds number range of 49,000 to 68,000. A set of composite characteristics Eppler 387 airfoils is assembled, giving wind tunnel values for Re between 60,000 and 200,000 and Williams code predictions for Re above 200,000. C.D.

A88-11210
SMOKE-WIRE AND THIN-FILM-GAUGE OBSERVATIONS OF LAMINAR SEPARATION BUBBLES ON AN NACA 23012-64 AIRFOIL SECTION
S. S. FISHER and D. C. HORGER (Virginia, University, Charlottesville) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 3 . London, Royal Aeronautical Society, 1986, p. 36.1-36.24. Research supported by the University of Virginia and U.S. Navy. refs

The smoke-wire flow visualization technique and the surface thin-film heat transfer gauge method are used here, together with surface pressure coefficient measurements, to characterize the behavior of laminar separation bubbles as they form on the suction side of a NACA 23012-64 airfoil section. Thin-film gauges are used to follow the development of unsteady flow patterns within these bubbles. Signals from the gauges are shown to be highly sensitive to flow fluctuations occurring within their immediate vicinity, up to frequencies as high as 1000 Hz. With these gauges, it is possible to detect the development of unstable oscillatory wave motions within the bubble-free shear layer which are quite small in magnitude. Signals from these gauges also provide a clear indication of transition to turbulence within this layer. It is possible to deduce the approximate point of boundary layer surface reattachment from these signals. C.D.

A88-11280
NUMERICAL SOLUTION OF COUPLED PROBLEMS OF SUPERSONIC FLOW PAST DEFORMABLE SHELLS OF FINITE THICKNESS [O CHISLENNOM RESHENII SVIAZANNYKH ZADACH SVERKHZVUKOVOGO OBTEKANIIA DEFORMIRUEMYKH OBOLOCHEK KONECHNOI TOLSHCHINY]
P. N. KOROTIN, I. B. PETROV, V. B. PIROGOV, and A. S. KHOLODOV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 27, Aug. 1987, p. 1233-1243. In Russian. refs

The problem considered here concerns supersonic flow of an inviscid non-heat-conducting gas past a blunt body which simultaneously undergoes elastic deformation. The body is formed by a single-layer or a multiple-layer shell of finite thickness with specified elastic-plastic properties; the shell may be stiffened by ribs. Under the effect of a head shock wave, the body may change its shape through deflections, thus affecting gas flow. The problem is solved by using an explicit grid scheme classified as a positive approximation scheme. V.L.

A88-12056
STRONG GAS INJECTION INTO SUPERSONIC FLOW WITH TURBULENT MIXING [SIL'NYI VDUV GAZA V SVERKHZVUKOVOI POTOK PRI TURBULENTNOM SMESHENII]
I. I. VIGDOROVICH Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 51, July-Aug. 1987, p. 600-610. In Russian. refs

Strong distributed injection of a gas through a porous plate into supersonic flow is analyzed for the case where the boundary layer is forced away from the plate and the injected gas is separated from the incoming flow by a turbulent mixing layer. A criterion for the detachment of the turbulent boundary layer during injection is formulated, as is a similarity rule reflecting the dependence of flow over the plate on the conditions at the end of the porous region. Pressure and injection layer thickness distribution curves are presented, and the force characteristics of the flow are calculated. V.L.

A88-12059
TRANSONIC EXPANSIONS [O TRANSZVUKOVYKH RAZLOZHENIIAKH]
A. L. BREZHNEV and I. A. CHERNOV Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 51, July-Aug. 1987, p. 688-690. In Russian. refs

The paper is concerned with the problem of finding particular solutions to inhomogeneous linearized transonic equations arising in transonic expansions that are expressed explicitly in terms of the principal solution to the Karman-Falkovich equation. First and second corrections to the solution for the Karman-Falkovich equation are derived. In contrast to the first correction, the second correction is shown to contain curvilinear integrals. V.L.

A88-12065
STABILITY OF SUPERSONIC FLOW OF AN IDEAL GAS WITH A HEAD SHOCK WAVE PAST CYLINDRICAL CHANNELS AND CAVITIES [OB USTOICHIVOSTI OBTEKANIIA TSILINDRICHESKIKH KANALOV I POLOSTEI SVERKHZVUKOVYM POTOKOM IDEAL'NOGO GAZA S GOLOVNOI UDARNOI VOLNOI]
V. T. GRIN', N. N. SLAVIANOV, and N. I. TILLIAEVA Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), July-Aug. 1987, p. 114-121. In Russian. refs

The stability of supersonic flow of an ideal gas with a head shock wave past cylindrical channels and cavities is investigated in the context of both distributed and concentrated parameter models using a first-order difference scheme with the isolation of the head shock. A stability analysis based on the linearized concentrated parameter model indicates that there exists a critical cavity length above which homogeneous supersonic flow becomes unstable. The qualitative results obtained on the basis of the concentrated parameter model are shown to support and complement the results obtained earlier from physical and numerical experiments with the distributed parameter model. V.L.

A88-12071
OXYGEN RECOMBINATION IN A SUPERSONIC COOLED FLOW [REKOMBINATSIIA KISLORODA V SVERKHZVUKOVOM OKHLAZHDAIUSHCHEMSIA POTOKE]
V. K. DUSHIN, I. E. ZABELINSKII, and O. P. SHATALOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), July-Aug. 1987, p. 160-165. In Russian. refs

Oxygen recombination in supersonic cooled flows is investigated here by the following two methods: by measuring ultraviolet emission absorption by oxygen molecules forming in a supersonic nozzle and by measuring gas pressure inside the nozzle. For this particular problem, the absorption spectroscopy method is found to be much more sensitive, making it possible to measure the recombination rate constant for low degrees of initial oxygen dissociation and at lower temperatures (1000 K). The piezoelectric method makes it possible to conduct measurements at higher temperatures for much higher (by an order of magnitude) concentrations of recombining atoms. The results obtained are compared with data in the literature, and an expression for the oxygen atom recombination rate constant is proposed. V.L.

A88-12073
EFFECT OF ENERGY RELEASE IN THE SHOCK LAYER ON THE SUPERSONIC FLIGHT OF BODIES [VLIIANIE ENERGOVYKELENIIA V UDARNOM SLOE NA SVERKHZVUKOVOI POLET TEL]
S. I. ARAFAILOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), July-Aug. 1987, p. 178-182. In Russian. refs

The presence of an energy release region in supersonic flow gives rise to perturbations propagating from the energy release source. The effect of such flow on a body is determined by the intensity of the source and by the configuration and location of the energy release region. Here, the dependence of the aerodynamic characteristic of a blunt cone on the parameters of

an energy release source is analyzed by using results of the numerical integration of equations of motion for a gas. V.L.

A88-12074
ANALYSIS OF SUPERSONIC HETEROGENEOUS FLOW IMPINGING ON AN OBSTACLE [RASCHET SVERKHZVUKOVOGO GETEROGENNOGO POTOKA PRI NATEKANII NA PREGRADU]
L. A. KANTOR, S. A. KANTOR, and M. P. STRONGIN Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), July-Aug. 1987, p. 182-185. In Russian. refs

A model is developed which describes supersonic motion of a high-temperature gas containing powder particles. Characteristics of the flow are analyzed for the case when the flow impinges on an obstacle, a typical case in plasma technology, particularly in the deposition of plasma-sprayed coatings. The results of the study demonstrate the possibility of the supersonic plasma spraying of coatings of fine (about 4 microns) powders. V.L.

A88-12075
OPTIMAL LIFTING WINGS WITH REQUIRED LONGITUDINAL BALANCING CHARACTERISTICS [OPTIMAL'NYE NESUSHCHIE KRYL'IA S TREBUEMYMI PRODOL'NO BALANSIROVOCHNYMI KHARAKTERISTIKAMI]
E. M. PROKHOROV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), July-Aug. 1987, p. 185-189. In Russian. refs

The paper is concerned with infinitely thin wings producing weak perturbations in supersonic flow of an ideal gas. For a given planform and free-stream Mach number, the optimum wing surface is determined by finding a limited function of the local angles of attack corresponding to a minimal drag coefficient for given pitching moment and lifting force coefficients. The problem is solved in terms of a class of piecewise constant functions for wings of complex geometry. V.L.

A88-12276#
FURTHER VISUALIZATION OF COMBINED WING TIP AND STARTING VORTEX SYSTEMS
P. FREYMUTH, W. BANK (Colorado, University, Boulder), and F. FINAISH AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1153-1159. refs
(Contract F49620-84-C-0065)

The combined wing tip and starting vortex systems of a variety of wing planforms have been visualized in a starting flow of constant acceleration. Movie sequences display the initial development of a variety of interesting vortex systems generated by these flow configurations. Vortices always formed closed systems in accordance with Helmholtz's law. Author

A88-12280*# National Cheng Kung Univ., Tainan (Taiwan).
REFINED NUMERICAL SOLUTION OF THE TRANSONIC FLOW PAST A WEDGE
S.-M. LIANG (National Cheng Kung University, Tainan, Republic of China) and K.-Y. FUNG (Arizona, University, Tucson) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1171-1175. Previously cited in issue 19, p. 2738, Accession no. A85-40709. refs
(Contract AF-AFOSR-83-0071; NGT-03-002-800)

A88-12282#
VISCID/INVISCID INTERACTION ANALYSIS OF SUBSONIC TURBULENT TRAILING-EDGE FLOWS
MARK BARNETT and JOSEPH M. VERDON (United Technologies Research Center, East Hartford, CT) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1184-1193. Previously cited in issue 08, p. 1041, Accession no. A87-22649. refs
(Contract N00014-83-C-0430)

A88-12284#
TWO-DIMENSIONAL TRANSONIC AERODYNAMIC DESIGN METHOD
MICHAEL B. GILES and MARK DRELA (MIT, Cambridge, MA) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1199-1206. refs
(Contract F49620-78-C-0084)

A88-12292#
EXACT AND ASYMPTOTIC EXPRESSIONS OF THE LIFT SLOPE COEFFICIENT OF AN ELLIPTIC WING
AHARON HAUPTMAN (California Institute of Technology, Pasadena) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1261, 1262. refs
(Contract NR PROJECT 062-737; N00014-82-C-0043; NSF MSM-81-18429-A03)

The Hauptman and Miloh (1987) analytical treatment for the classical lifting surface problem of an elliptic planform in incompressible flow (which may be either steady or unsteady) is based on the expansion of the linearized acceleration potential in a series of ellipsoidal harmonics, and leads to very simple closed-form expressions for the aerodynamic coefficients in terms of the arbitrary aspect ratio. The asymptotic forms into which these exact expressions can be easily expanded, to any order of the aspect ratio or its inverse (in the respective cases of high and low aspect ratios), are presently obtained and compared with other existing approximations. O.C.

A88-12293#
GLOBAL MARCHING TECHNIQUE FOR PREDICTING SEPARATED FLOWS OVER ARBITRARY AIRFOILS
AHMAD A. M. HALIM (USAF, Institute of Technology, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1263-1266. Previously cited in issue 08, p. 1043, Accession no. A87-22725.

A88-12483
THE DEVELOPMENT OF WING THEORY [DIE ENTWICKLUNG DER TRAGFLUEGELTHEORIE]
R. EPPLER (Stuttgart, Universitaet, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, May-June 1987, p. 133-144. In German. refs

The induced drag for wings of finite thickness is computed here from lifting line theory with vortex roll-up, and first results are presented. The lifting line is located at the trailing edge of the wing. The planform with straight trailing edge and swept-back leading edge is shown to be advantageous. A dramatic difference appears between winglets above and below the wing; this difference is confirmed by simple experiments on free-flying models. C.D.

A88-13077#
WING DESIGN WITH A THREE-DIMENSIONAL TRANSONIC INVERSE METHOD
TADAYUKI TANIOKA, JUNICHI MIYAKAWA, JUN OGINO, and KANICHI AMANO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 582-586. In Japanese.

Wing design performed using the ISOBAR technique with a three-dimensional transonic inverse method is described, and wind-tunnel test results are presented. The proposed approach was used to design the wings for the next-generation civilian aircraft with a length of 37.5 m, a width of 35.5 m, a wing area of 120 sq m, a maximum takeoff weight of 64.4 tons, and an occupancy of 150 passengers. The air pressure distribution was determined. S.H.

A88-13078#
AN AERODYNAMIC DESIGN STUDY OF TRANSONIC TRANSPORT WINGS
KOHEI TANAKA, MASAAKI NAKADATE, and KANICHI AMANO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 587-591. In Japanese. refs

An aerodynamic wing design study for a transonic transport aircraft carrying 150 passengers for relatively short distances is carried out. Two-dimensional transonic airfoil design is described, and wind-tunnel-test results are reported. It is shown that the preferred wing is of the front-and-rear loading type, and that M(DD) control can be achieved by the adjustment of the wing cross-section area distribution. S.H.

A88-13079#
HIGH-LIFT-DEVICE DESIGN AND LOW-SPEED WIND-TUNNEL TEST
MASANOBU OGAKI, TAKESHI WATANABE, and KANICHI AMANO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 592-599. In Japanese.

The design of high-lift devices for transport aircraft is described, and wind-tunnel-test results are presented. A parametric study of the positioning of the high-lift devices is carried out using a method of two-dimensional boundary layer calculation, and the parameters for flap and slat positions are determined. Reynolds number effects in the wind tunnel are examined. S.H.

A88-13096* Kansas Univ., Lawrence.
OBSERVATIONS AND ANALYSES OF NATURAL LAMINAR FLOW OVER A NONLIFTING AIRFRAME SURFACE
PAUL M. H. W. VIJGEN (Kansas, University, Lawrence) SAE, General Aviation Aircraft Meeting and Exposition, Wichita, KS, Apr. 28-30, 1987. 14 p. refs
(Contract NAG1-345)
(SAE PAPER 871020)

A NASA-sponsored flight experiment program has been conducted with a twin-engined, propeller-driven general aviation aircraft, in order to ascertain the transition location and mode over the nonaxisymmetric fuselage forebody. Attention is given to the transition instrumentation layout and the flight test plan matrix. The results obtained for transition in varying freestream and propeller conditions will furnish insights into transition mechanisms and the significance of crossflow instability during transition in realistic nonaxisymmetric fuselage forebodies at angles of attack and sideslip. O.C.

N88-10005# Karlsruhe Univ. (West Germany). Stroemungsmechanische Bemessungsgrundlagen fuer Bauwerke.
POSSIBILITIES FOR THE MODELING OF DYNAMICALLY LOADED CYLINDRICAL STRUCTURAL PARTS IN THE WIND TUNNEL [MODELLIERUNGSMOEGLICHKEITEN DER DYNAMISCHEN BELASTUNG ZYLINDRISCHER BAUWERKE IM WINDKANAL]
F. MENACHER and J. MAIER-ERBACHER 1987 38 p In GERMAN
(KU-SFB-210/T/24; ETN-87-90370) Avail: NTIS HC A03/MF A01

The loading of cylindrical structures by the natural wind and its modelling in the wind tunnel were investigated to obtain information on random loading of thin structures. The fundamentals of random vibrations of structures under wind loading, namely the theory of multiple input linear systems, are presented. The theoretical and experimental determination of the wind speed correlations and the pressure on the structure are discussed. Theoretically as well as experimentally the vertical and horizontal transfer functions, describing the relation between speed and pressure, were separately analyzed. The errors due to this separation are discussed. The comparison between natural model measurements becomes difficult if de-integrated vortex parts reach the cylindrical structure. ESA

N88-10006# National Aerospace Lab., Amsterdam (Netherlands). Fluid Dynamics Div.
A TRANSONIC MODEL REPRESENTATION FOR TWO-DIMENSIONAL WALL INTERFERENCE ASSESSMENT
J. SMITH Feb. 1986 23 p
(NLR-TR-86026-U; B8709827; ETN-87-90823) Avail: NTIS HC A03/MF A01

It is shown that for a two-dimensional airfoil a subsonic formulation may underestimate the actual displacement effect by up to 50% for supercritical flow conditions. Extension of the subsonic model representation by a transonic doublet, derived in an approximative way, is shown to constitute a considerable improvement. ESA

N88-10007*# FWG Associates, Inc., Tullahoma, Tenn.
ANALYSES AND ASSESSMENTS OF SPAN WISE GUST GRADIENT DATA FROM NASA B-57B AIRCRAFT Final Report
WALTER FROST, HO-PEN CHANG, and ERIK A. RINGNES Aug. 1987 350 p
(Contract NAS1-17989)
(NASA-CR-178288; NAS 1.26:178288) Avail: NTIS HC A15/MF A01 CSCL 01A

Analysis of turbulence measured across the airfoil of a Cambera B-57 aircraft is reported. The aircraft is instrumented with probes for measuring wind at both wing tips and at the nose. Statistical properties of the turbulence are reported. These consist of the standard deviations of turbulence measured by each individual probe, standard deviations and probability distribution of differences in turbulence measured between probes and auto- and two-point spatial correlations and spectra. Procedures associated with calculations of two-point spatial correlations and spectra utilizing data were addressed. Methods and correction procedures for assuring the accuracy of aircraft measured winds are also described. Results are found, in general, to agree with correlations existing in the literature. The velocity spatial differences fit a Gaussian/Bessel type probability distribution. The turbulence agrees with the von Karman turbulence correlation and with two-point spatial correlations developed from the von Karman correlation. Author

N88-10008*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ADVANCED TURBOPROP WING INSTALLATION EFFECTS MEASURED BY UNSTEADY BLADE PRESSURE AND NOISE
LAURENCE J. HEIDELBERG and RICHARD P. WOODWARD 1987 23 p Presented at the 11th Aeroacoustics Conference, Sunnyvale, Calif., 19-21 Oct. 1987; sponsored by AIAA
(NASA-TM-100200; E-3737; NAS 1.15:100200; AIAA-87-2719)
Avail: NTIS HC A03/MF A01 CSCL 01A

A single rotation model propeller (SR-7A) was tested at simulated takeoff/approach conditions (Mach 0.2), in the NASA Lewis 9- by 15-Ft Anechoic Wind Tunnel. Both unsteady blade surface pressures and noise measurements were made for a tractor configuration with propeller/straight wing and propeller alone configurations. The angle between the wing chord and propeller axis (droop angle) was varied along with the wing angle of attack to determine the effects on noise and unsteady loading. A method was developed that uses unsteady blade pressure measurements to provide a quantitative indication of propeller inflow conditions, at least for a uniform (across the propeller disk) inflow angle. The wing installation caused a nearly uniform upwash at the propeller inlet as evidenced by the domination of the pressure spectra by the first shaft order. This inflow angle increased at a rate of almost 150 percent of that of the wing angle-of-attack for a propeller-wing spacing of 0.54 wing chords at a constant droop angle. The flyover noise, as measured by the maximum blade passing frequency level, correlates closely with the propeller inflow angle (approx. 0.6 dB per degree of inflow angle) for all droop angles and wing angles of attack tested, including the propeller alone data. Large changes in the unsteady pressure responses on the suction surface of the blade were observed as the advance ratio was varied. The presence of a leading edge vortex may explain this behavior since

changes in the location of this vortex would change with loading (advance ratio). Author

N88-10009*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
WIND-TUNNEL INVESTIGATION OF A FULL-SCALE GENERAL AVIATION AIRPLANE EQUIPPED WITH AN ADVANCED NATURAL LAMINAR FLOW WING
DANIEL G. MURRI and FRANK L. JORDAN, JR. Nov. 1987 136 p
(NASA-TP-2772; L-16283; NAS 1.60:2772) Avail: NTIS HC A07/MF A01 CSCL 01A

An investigation was conducted in the Langley 30- by 60-Foot Wind Tunnel to evaluate the performance, stability, and control characteristics of a full-scale general aviation airplane equipped with an advanced laminar flow wing. The study focused on the effects of natural laminar flow and advanced boundary layer transition on performance, stability, and control, and also on the effects of several wing leading edge modifications on the stall/departure resistance of the configuration. Data were measured over an angle-of-attack range from -6 to 40 deg and an angle-of-sideslip range from -6 to 20 deg. The Reynolds number was varied from 1.4 to 2.4 x 10 to the 6th power based on the mean aerodynamic chord. Additional measurements were made using hot-film and sublimating chemical techniques to determine the condition of the wing boundary layer, and wool tufts were used to study the wing stall characteristics. The investigation showed that large regions of natural laminar flow existed on the wing which would significantly enhance cruise performance. Also, because of the characteristics of the airfoil section, artificially tripping the wing boundary layer to a turbulent condition did not significantly effect the lift, stability, and control characteristics. The addition of a leading-edge droop arrangement was found to increase the stall angle of attack at the wingtips and, therefore, was considered to be effective in improving the stall/departure resistance of the configuration. Also the addition of the droop arrangement resulted in only minor increases in drag. Author

N88-10010# Office of Naval Research, London (England).
INTERNATIONAL CONFERENCE ON THE AERODYNAMICS AT LOW REYNOLDS NUMBERS BETWEEN 10(4) AND 10(6)
THOMAS J. MUELLER 31 Aug. 1987 19 p Conference held in London, England, 15-18 Oct. 1986
(ONRL-7-023-C) Avail: NTIS HC A03/MF A01

Presentations made at the International Conference on Aerodynamics at Low Reynolds Numbers, which took place in London from 15 to 18 October 1986, are reviewed. Topics include airfoil design methods and verification, airfoil calculation methods, low Reynolds number research at NASA Langley Research Center, unsteady aerodynamic characteristics, wind turbine applications, separation bubbles, experimental facilities and testing, and remotely piloted vehicles. Author

N88-10011*# Notre Dame Univ., Ind. Dept. of Aerospace and Mechanical Engineering.
THE STRUCTURE OF SEPARATED FLOW REGIONS OCCURRING NEAR THE LEADING EDGE OF AIRFOILS INCLUDING TRANSITION Semiannual Status Report, May - Oct. 1987
THOMAS J. MUELLER Oct. 1987 37 p
(Contract NSG-1419)
(NASA-CR-181434; NAS 1.26:181434) Avail: NTIS HC A03/MF A01 CSCL 01A

All the time and effort was directed toward acquiring, reducing, and analyzing more hot-wire anemometer data. Some static pressure distribution data were also acquired to support the analysis of the velocity profile data. Laser Doppler Velocimetry data were not acquired due to equipment problems. Included were seven combinations of chord Reynolds number, angle of attack, and acoustic forcing using the NACA 663-018 airfoil. This research has as its objective the detailed documentation of the structure and behavior of the transitional separation bubble and the redeveloping boundary layer after reattachment over an airfoil at low Reynolds numbers. The intent is to further the understanding of the complex flow phenomena so that analytic methods for predicting their formulation and development can be improved. These analytic techniques have applications in the design and performance prediction of airfoils operating in the low Reynolds number flight regime. Author

N88-10012*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
INTEGRATION OF DYNAMIC, AERODYNAMIC AND STRUCTURAL OPTIMIZATION OF HELICOPTER ROTOR BLADES Semiannual Status Report No. 2, 14 Apr. - 13 Oct. 1987
DAVID A. PETERS 2 Nov. 1987 34 p
(Contract NAG1-710)
(NASA-CR-181441; NAS 1.26:181441) Avail: NTIS HC A03/MF A01 CSCL 01A

The purpose of the research is to study the integration of structural, dynamic, and aerodynamic considerations in the design-optimization process for helicopter rotorblades. This is to be done in three phases. Task 1 is to bring on-line computer codes that could perform the finite-element frequency analyses of rotor blades. The major features of this program are summarized. The second task was to bring on-line an optimization code for the work. Several were tried and it was decided to use CONMIN. Explicit volume constraints on the thicknesses and lumped masses used in the optimization were added. The specific aeroelastic constraint that the center of mass must be forward of the quarter chord in order to prevent flutter was applied. The bending-torsion coupling due to cg-ea offset within the blade cross section was included. Also included were some very simple stress constraints. The first three constraints are completed, and the fourth constraint is being completed. B.G.

N88-10013*# Kansas Univ. Center for Research, Inc., Lawrence. Flight Research Lab.
TRANSONIC ANALYSIS AND DESIGN OF AXISYMMETRIC BODIES IN NONUNIFORM FLOW
JEN-FU CHANG and C. EDWARD LAN Nov. 1987 77 p
(Contract NAG1-308)
(NASA-CR-4101; NAS 1.26:4101; CRINC-FRL-602-3) Avail: NTIS HC A05/MF A01 CSCL 01A

An inviscid nonuniform axisymmetric transonic code was developed for applications in analysis and design. Propfan slipstream effect on pressure distribution for a body with and without sting was investigated. Results show that nonuniformity causes pressure coefficient to be more negative and shock strength to be stronger and more rearward. Sting attached to a body reduced the pressure peak and moves the rear shock forward. Extent and Mach profile shapes of the nonuniformity region appeared to have little effect on the pressure distribution. Increasing nonuniformity magnitude made pressure coefficient more negative and moved the shock rearward. Design study was conducted with the CONMIN optimizer for an ellipsoid and a body with the NACA-0012 counter. For the ellipsoid, the general trend showed that to reduce the pressure drag, the front portion of the body should be thinner and the contour of the rear portion should be flatter than the ellipsoid. For the design of a body with a sharp trailing edge in transonic flow with an initial shape given by the NACA-0012 contour, the pressure drag was reduced by decreasing the nose radius and increasing the thickness in the aft portion. Drag reduction percentages are given. Author

N88-10014# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
DISPERSION IN THE WAKE OF AIRCRAFT: AN INVESTIGATION OF THE EFFECTS OF A GROUND PLANE ON TRAILING VORTICES. LITERATURE SURVEY
J. K. HARVEY and T. R. STEINER Jun. 1986 69 p
(IC-AERO-REP-86-04; ISSN-0308-7247; ETN-87-90689) Avail: NTIS HC A04/MF A01

Physical processes of trailing vortice are discussed, and the complexities and subtleties of aircraft wake flow are explored. A

literature survey detects little work of direct relevance to the problem of dispersion of aircraft wake material, especially near the ground. However, problems and likely areas of useful research are identified. ESA

N88-10015# Technische Univ., Berlin (West Germany). Fachbereich Verkehrswesen.
A METHOD FOR THE CALCULATION OF TRANSONIC FLOWS FOR THE CONTROL OF ADAPTIVE WIND TUNNELS Ph.D. Thesis [VERFAHREN ZUR BERECHNUNG TRANSSONISCHER STROEMUNGEN FUER DIE REGELUNG ADAPTIVER WINDKANAELE]
RAINER REBSTOCK 1986 122 p In GERMAN Sponsored by the Bundesministerium fuer Forschung und Technologie, West Germany
(ETN-87-90411) Avail: NTIS HC A06/MF A01

Numerical methods for the adjustment of three-dimensional, adaptive test sections for wind tunnel walls were developed. The required wall form was designed by the stepwise modification of a starting contour. The bad convergence characteristics of the classical iterative adaptive method in the three-dimensional case were demonstrated theoretically and by a numerical simulation. It is shown that the replacement of the constant control factor by a matrix, which takes into account the remote Mach number and the test section geometry, allows the calculation of the adapted wall contour practically in one step. A method for the testing of three-dimensional models in wind tunnels with two flexible walls is proposed. Wall deviations, allowing the suppression of interferences on the model axis, are proposed. ESA

N88-10016# Technische Hochschule, Darmstadt (West Germany). Fachbereich Maschinenbau.
INVESTIGATIONS OF SEPARATED FLOW STATES ON WINGS OF MEDIUM ASPECT RATIO TAKING INTO ACCOUNT THE WIND TUNNEL INTERFERENCE PROBLEM Ph.D. Thesis [UNTERSUCHUNGEN ABGELOESTER STROEMUNGSZUSTAENDE AN TRAGFLUEGELN MITTLERER STRECKUNG UNTER BERUECKSICHTIGUNG DES WINDKANALINTERFERENZPROBLEMS PROBLEMS]
JOHANNES KEIL 1985 208 p In GERMAN
(ETN-87-90437) Avail: NTIS HC A10/MF A01

Wind tunnel experiments were conducted for the investigation of separated, subsonic flow about wings in the range of high angles of attack. The pressure distributions and aerodynamic coefficients of the wings were measured. The effect of the design parameters on the separation behavior was deduced from measurements on five wings of equal aspect ratio, but different sweep. The measurements were evaluated with a calculation method which considers the buoyancy as well as the displacement correction. Corrections were determined for the open and the closed wind tunnel test section with circular cross section with a straight rectangular wing. ESA

N88-10018# Royal Aircraft Establishment, Farnborough (England).
ON THE PROSPECTS FOR INCREASING DYNAMIC LIFT
D. G. MABEY May 1986 37 p
(RAE-TM-AERO-2068; BR100237; ETN-87-90955) Avail: NTIS HC A03/MF A01

Research, mainly at low speeds, into the development of dynamic lift is reviewed. Sudden movement of aerodynamic surfaces can generate dynamic lift due to the transient development of separated flow. These dynamic effects are large and well established for airfoils. They are considered likely to be small for highly swept wings and negligible for slender wings, but there is little experimental evidence to support this inference. Dynamic lift might be increased if conventional sinusoidal motions can be replaced by appropriate periodic sawtooth motions. The control of large-scale flow separations by rapid movements of aerodynamic surfaces requires further investigation and a program of wind tunnel tests to resolve controversial issues is suggested. ESA

N88-10765*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
COMPARISON OF WIND TUNNEL AND FLIGHT TEST AFTERBODY AND NOZZLE PRESSURES FOR A TWIN-JET FIGHTER AIRCRAFT AT TRANSONIC SPEEDS
JACK NUGENT and ODIS C. PENDERGRAFT, JR. Mar. 1987 125 p
(NASA-TP-2588; H-1214; NAS 1.60:2588) Avail: NTIS HC A06/MF A01 CSCL 01A

Afterbody and nozzle pressures measured on a 1/12-scale model and in flight on a twin-jet fighter aircraft were compared as Mach number varied from 0.6 to 1.2, Reynolds number from 17.5 million to 302.5 million, and angle of attack from 1 to 7 deg. At Mach 0.6 and 0.8, nozzle pressure coefficient distributions and nozzle axial force coefficients agreed and showed good recompression. At Mach 0.9 and 1.2, flow complexity caused a loss in recompression for both flight and wind tunnel nozzle data. The flight data exhibited less negative values of pressure coefficient and lower axial force coefficients than did the wind tunnel data. Reynolds number effects were noted only at these Mach numbers. Jet temperature and mass flux ratio did not affect the comparisons of nozzle axial flow coefficient. At subsonic speeds, the levels of pressure coefficient distributions on the upper fuselage and lower nacelle surfaces for flight were less negative than those for the model. The model boundary layer thickness at the aft rake station exceeded that for the forward rake station and increased with increasing angle of attack. The flight boundary layer thickness at the aft rake station was less than that for the forward rake station and decreased with increasing angle of attack. Author

N88-10767# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.
THE AEROTHERMODYNAMIC ENVIRONMENT FOR HOLES IN HYPERSONIC CONFIGURATIONS
JOHN J. BERTIN, WILLIAM J. TEDESCHI, ALBINO C. BUSTAMANTE, and ERIC W. REECE (Sandia National Labs., Albuquerque, N. Mex.) Aug. 1987 34 p Presented at the AIAA Aerodynamics Flight Mechanics Conference, Monterey, Calif., 17-19 Aug. 1987
(Contract DE-AC04-76DP-00789)
(DE87-014651; SAND-86-2875C-FP; CONF-870830-2-FP) Avail: NTIS HC A03/MF A01

A series of test programs have been conducted in Tunnel B of the Arnold Engineering Development Center (AEDC) in which wedges and spherically-blunted cones (with surface openings and base vents) were exposed to a Mach 8 stream. Measurements of the heat transfer and pressure from the recompression face of the external surface port were compared with the corresponding values computed using the rotational method-of-characteristics for a nonadiabatic, two-dimensional flow. The computed flow field provided reasonable estimates of the experimental measurements. Over the range of test conditions, the expansion-fan flow directly impinged on only a small fraction of the surface port recompression face and it immersed the entire recompression face. The recompression pressures and heat-transfer rates could be correlated as a function of the cavity pressure ratio. DOE

N88-10771*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EFFECT OF EMPENNAGE ARRANGEMENT ON SINGLE-ENGINE NOZZLE/AFTERBODY STATIC PRESSURES AT TRANSONIC SPEEDS
WILLIAM P. HENDERSON and JAMES R. BURLEY, II Nov. 1987 230 p
(NASA-TP-2753; L-16223; NAS 1.60:2753) Avail: NTIS HC A11/MF A01 CSCL 01A

An investigation has been conducted in the Langley 16-Foot Transonic Tunnel to determine the effects on empennage arrangement on single-engine nozzle/afterbody static pressures. Tests were done at Mach numbers from 0.60 to 1.20, nozzle pressure ratios from 1.0 (jet off) to 8.0. and angles of attack from -3 to 9 deg (at jet off conditions), depending on Mach number. Three empennage arrangements (aft, staggered, and forward) were

investigated. Extensive measurements were made of static pressure on the nozzle/afterbody in the vicinity of the tail surfaces.
Author

N88-10772*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
WALL INTERFERENCE TESTS OF A CAST 10-2/DOA 2 AIRFOIL IN AN ADAPTIVE-WALL TEST SECTION
RAYMOND E. MINECK Dec. 1987 100 p
(NASA-TM-4015; L-16334; NAS 1.15:4015) Avail: NTIS HC A05/MF A01 CSCL 01A

A wind-tunnel investigation of a CAST 10-2/DOA 2 airfoil model has been conducted in the adaptive-wall test section of the Langley 0.3-Meter Transonic Cryogenic Tunnel (TCT) and in the National Aeronautical Establishment High Reynolds Number Two-Dimensional Test Facility. The primary goal of the tests was to assess two different wall-interference correction techniques: adaptive test-section walls and classical analytical corrections. Tests were conducted over a Mach number range from 0.3 to 0.8 and over a chord Reynolds number range from 6 million to 70 million. The airfoil aerodynamic characteristic from the tests in the 0.3-m TCT have been corrected for wall interference by the movement of the adaptive walls. No additional corrections for any residual interference have been applied to the data, to allow comparison with the classically corrected data from the same model in the conventional National Aeronautical Establishment facility. The data are presented graphically in this report as integrated force-and-movement coefficients and chordwise pressure distributions. Author

N88-10773*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
INTERGRATION EFFECTS OF D-SHAPED, UNDERWING, AFT-MOUNTED, SEPARATE-FLOW, FLOW-THROUGH NACELLES ON A HIGH-WING TRANSPORT
MILTON LAMB, JOHN R. CARLSON, and ODIS C. PENDERGRAFT, JR. Nov. 1987 24 p
(NASA-TM-4018; L-16342; NAS 1.15:4018) Avail: NTIS HC A03/MF A01 CSCL 01A

An experimental investigation was conducted in the Langley 16-Foot Transonic Tunnel at freestream Mach numbers from 0.70 to 0.82 and angles of attack from -3.0 to 4.0 deg to determine the integration effects of D-shaped, underwing, aft-mounted, separate-flow, flow-through nacelles on a high-wing transonic transport configuration. The results showed that the aft-mounted nacelle/pylon produced an increase in lift over that of the wing-body configuration by pressurizing much of the wing lower surface in front of the pylon. For the D-shaped nacelle, a substantial region of supersonic flow over the wing, aft of the lip of the nacelle, cancelled the reduction in drag caused by the increase in pressures ahead of the lip, to increase interference and form drag compared with a similar circular-shaped nacelle. The installed drag of the D=shaped nacelle was essentially the same as that of an aft-mounted circular nacelle from a previous investigation.
Author

N88-10776*# National Aeronautics and Space Administration, Washington, D.C.
CALCULATION OF AERODYNAMIC HEAT TRANSFER FOR BLUNT-NOSED THIN WINGS AT DIFFERENT ANGLES OF ATTACK AT SUPERSONIC SPEEDS
SHUXUAN XU Nov. 1987 17 p Transl. into ENGLISH from Acta Aerodynamica Sinica (People's Republic of China), v. 4, Dec. 1986 p 398-405 Original language document was announced in IAA as A87-28338 Transl. By Kanner (Leo) Associates, Redwood City, Calif. Prepared by China Univ. of Science and Technology, People's Republic of China
(Contract NASW-4005)
(NASA-TT-20127; NAS 1.77:20127) Avail: NTIS HC A03/MF A01 CSCL 01A

A method for calculating aerodynamic heat transfer on thin wings at angles of attack is provided, based on the assumption of small cross flow and the calculation of an infinite cylinder. It is valid in the range of supersonic and hypersonic speeds. The method does not require calculation of the details of the stream lines and can be used for various swept wings at moderate angle of attack or yaw angle. A comparison between theoretical and experimental results is given. Author

N88-10777*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
ANALYTICAL MODELING OF HELICOPTER STATIC AND DYNAMIC INDUCED VELOCITY IN GRASP
DONALD L. KUNZ and DEWEY H. HODGES (Georgia Inst. of Tech., Atlanta.) Nov. 1987 10 p
(NASA-TM-100026; A-87341; NAS 1.15:100026; USAAVSCOM-TR-87-A-11) Avail: NTIS HC A02/MF A01 CSCL 01A

The methodology used by the General Rotorcraft Aeromechanical Stability Program (GRASP) to model the characteristics of the flow through a helicopter rotor in hovering or axial flight is described. Since the induced flow plays a significant role in determining the aeroelastic properties of rotorcraft, the computation of the induced flow is an important aspect of the program. Because of the combined finite-element/multibody methodology used as the basis for GRASP, the implementation of induced velocity calculations presented an unusual challenge to the developers. To preserve the modelling flexibility and generality of the code, it was necessary to depart from the traditional methods of computing the induced velocity. This is accomplished by calculating the actuator disc contributions to the rotor loads in a separate element called the air mass element, and then performing the calculations of the aerodynamic forces on individual blade elements within the aeroelastic beam element. Author

N88-10779*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
A NATURAL LOW FREQUENCY OSCILLATION IN THE WAKE OF AN AIRFOIL NEAR STALLING CONDITIONS
K. B. M. Q. ZAMAN and D. J. MCKINZIE 1987 17 p Prepared for presentation at the 26th Aerospace Sciences Meeting, Reno, Nev., 11-14 Jan. 1988; sponsored by AIAA
(NASA-TM-100213; E-3822; NAS 1.15:100213; AIAA-88-0131) Avail: NTIS HC A03/MF A01 CSCL 01A

An unusually low frequency oscillation in the flow over an airfoil was explored experimentally. Wind tunnel measurements were carried out with a two dimensional airfoil model at a chord Reynolds number of 100,000. During deep stall the usual bluff-body shedding occurred at a Strouhal number. But at the onset of stall a low frequency periodic oscillation occurred, the corresponding Strouhal number being an order of magnitude lower. The phenomenon occurred in relatively unclean flow when the freestream turbulence was raised to 0.4 percent, but did not in the cleaner flow with turbulence intensity of 0.1 percent. It could also be produced by certain high frequency acoustic excitation. Details of the flow field are compared between a case of low frequency oscillation at alpha = 15 deg and a case of bluff-body shedding at alpha = 22.5 deg. The origin of the low frequency oscillation traces to the upper surface of the airfoil and is seemingly associated with the periodic formation and breakdown of a large separation bubble. The intense flow fluctuations impart significant unsteady forces to the airfoil but diminish rapidly within a distance of one chord from the trailing edge. Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A88-10658
FLIGHT SAFETY AND RISK [FLUGSICHERHEIT UND RISIKO]
ALEXANDER RIECHE (Berlin, Humboldt-Universitaet, German Democratic Republic) Technisch-oekonomische Information der zivilen Luftfahrt (ISSN 0232-5012), vol. 23, no. 3, 1987, p. 126-128. In German.

Theoretical aspects of flight safety and risks are discussed, and their manifestations as concrete risks are considered. Risk is addressed from the standpoint of Marxist socialist ideology in an abstract way. A philosophical and abstract discussion of risk reduction is presented. C.D.

A88-12644
AIRCRAFT AND EQUIPMENT FACTORS IN THE OCCURRENCE OF SUSPENSION LINE TWISTS WITH U.S. ARMY PARACHUTES
WILLIAM P. BURKE (U.S. Army, Research Institute for the Behavioral and Social Sciences, Fort Benning, GA) Human Factors (ISSN 0018-7208), vol. 29, Aug. 1987, p. 483-492.

Data were collected by self-report for the trainees of two classes of the Basic Airborne Course at Fort Benning, GA, who were asked if they had developed twists in their suspension line during each of the five jumps of the course. These data were then related to the conditions of deployment for each jump - type of parachute used, type of equipment carried, type of aircraft jumped from, and so forth. The proportion of jumpers with twists during a given jump with its associated conditions of deployment was compared by the chi-square test with the proportion of jumpers with twists from other jumps made under different conditions of deployment. No effect of type of parachute on the occurrence of twists was detected, but a strong and significant effect of combat equipment was associated with an increase in the proportion of twists. There was, in addition, a significant but slightly smaller effect attributable to the type of aircraft used for jumps, with more twists occurring during jumps from the C-141 than during jumps from the C-123. Author

N88-10020# Luftfahrt-Bundesamt, Brunswick (West Germany). Flugunfalluntersuchungsstelle.
AIRCRAFT ACCIDENTS Annual Report, 1984 [FLUGUNFALL JAHRESBERICHT, 1984]
Sep. 1986 120 p In GERMAN
(JB-84; ISSN-0178-8094; ETN-87-90396) Avail: NTIS HC A06/MF A01

All accidents in 1984 with German aircraft at home and abroad, as well as with foreign aircraft in Germany, which were announced to the aircraft investigation service, are listed. Concepts used in the examination of aircraft accidents are explained. The accidents are listed for aircrafts above 5.7T, between 2 and 5.7T, below 2T, helicopters, powered gliders, gliders, parachutes, hang gliders, ultralight aircraft, balloons, and other types of aircraft. ESA

N88-10021*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
FULL-SCALE TRANSPORT CONTROLLED IMPACT DEMONSTRATION PROGRAM Final Summary Report
Sep. 1987 82 p Prepared in cooperation with NASA, Ames Research Center, Moffett Field, Calif. and FAA, Atlantic City, N.J.
(NASA-TM-89642; NAS 1.15:89642; DOT/FAA/CT-87/10) Avail: NTIS HC A05/MF A01 CSCL 01C

The Federal Aviation Administration (FAA) and NASA conducted a full-scale air-to-surface impact-survivable impact demonstration with a remotely piloted transport aircraft on 1 December 1984, at Edwards Air Force Base, California. The test article consisted of experiments, special equipment, and supporting systems, such as antimisting kerosene (AMK), crashworthiness structural/restraint, analytical modeling, cabin fire safety, flight data recorders, post-impact investigation, instrumentation/data acquisition systems, remotely piloted vehicle/flight control systems, range and flight safety provisions, etc. This report describes the aircraft, experiments, systems, activities, and events which lead up to the Controlled Impact Demonstration (CID). An overview of the final unmanned remote control flight and sequence of impact events are delineated. Preliminary post CID observations are presented. Author

N88-10781# National Transportation Safety Board, Washington, D. C. Bureau of Field Operations.
AIRCRAFT ACCIDENT REPORTS, BRIEF FORMAT, US CIVIL AND FOREIGN AVIATION. ISSUE NUMBER 1: 1986 ACCIDENTS
28 May 1987 410 p
(PB87-916903; NTSB/AAB-87/03) Avail: NTIS HC A18/MF A01; also available on subscription, North American Continent HC $185.00/year, all others write for quote CSCL 01C

The publication contains selected aircraft accident reports in Brief Format occurring in U.S. civil and foreign aviation operations during Calendar Year 1986. Approximately 200 General Aviation and Air Carrier accidents contained in the publication represent a random selection. The publication is issued irregularly, normally eighteen times each year. The Brief Format represents the facts, conditions, circumstances and probable cause(s) for each accident. GRA

N88-10782# Transportation Research Board, Washington, D.C.
ISSUES IN AIR TRANSPORT AND AIRPORT MANAGEMENT
J. P. SCHWIETERMAN, F. A. SPENCER, M. GHAFOURI, T. N. LAM, and J. R. G. BRANDER 1986 58 p
(PB87-204509; TRB/TRR-1094; ISBN-309-04114-7; LC-87-7628) Avail: NTIS HC A04/MF A01 CSCL 01C

The six papers in this report deal with the following: alternatives to the hub; a survey of nonstop air service opportunities; accessibility in the deregulated domestic airline network; air transport deregulation and airport congestion; the search for efficient solutions; methodology for planning and operations management of airport terminal facilities; a prescription for efficient management of the Canadian Government's civilian aircraft fleet; and analyzing the financial impact on airports of remote airport ground transportation. GRA

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

A88-10437
ROBOTIC AIR VEHICLE - A PILOT'S PERSPECTIVE
JESSE BLAIR (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) and KARL E. SCHRICKER (Texas Instruments, Inc., Dallas) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 2, Sept. 1987, p. 8-11.

The algorithms and technological features needed to develop robotic air vehicles (RAVs) are examined. The proposed RAV is an unmanned air vehicle capable of passive terrain following, terrain avoidance, obstacle avoidance, and autonomous navigation. The need to combine the remotely piloted vehicle airframe and propulsion concept with AI is discussed. RAV simulations and demonstrations have been designed. The simulations will evaluate the functioning of the RAV software algorithms during various mission scenarios, and the demonstrations will test the ability of RAVs to fly a jet aircraft, execute an instrument/qualification check, a mission ready check, and a tactical qualification check. I.F.

A88-10676
MODERN TECHNOLOGY IN POSITIONING AND NAVIGATION; NAVIGATION MEETING, DUESSELDORF, FEDERAL REPUBLIC OF GERMANY, MAY 6-8, 1987, REPORTS [MODERNE TECHNOLOGIE IN ORTUNG UND NAVIGATION; NAVIGATIONSTAGUNG, DUESSELFDORF, FEDERAL REPUBLIC OF GERMANY, MAY 6-8, 1987, VORTRAEGE]
Meeting organized and sponsored by the Deutsche Gesellschaft fuer Ortung und Navigation. Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, 294 p. In German. For individual items see A88-10677 to A88-10688.

Technological and applications aspects of state-of-the-art positioning and navigation equipment are discussed in reviews and reports, with an emphasis on developments in the FRG. The general topics addressed include user perspectives on the impact of modern technology; the current technological status and future development trends; and applications to land, sea, and air transportation. Consideration is given to the physical and technological bases of past and present navigation methods; the impact of modern technology on ATC, ship-crew training, and transport-aircraft avionics; radio, radar, and satellite positioning systems; vessel traffic services; onboard collision-avoidance systems; and proposals for a European data network to acquire, process, and display air-traffic information. T.K.

A88-10677#
BMFT-SUPPORTED PROJECTS IN THE FIELDS POSITION-FINDING, NAVIGATION, AND TRAFFIC SAFETY [VOM BMFT GEFOERDERTE PROJEKTE DER BEREICHE ORTUNG, NAVIGATION UND VERKEHRSSICHERUNG]
H. A. HERTRICH (BMFT, Bonn, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 159-168. In German.

The current status of air navigation, positioning, and traffic-safety R&D projects sponsored by the FRG Ministry of Science and Technology (BMFT) is reviewed; sample results are summarized; and future trends are indicated. The primary aims of the BMFT programs include (1) assuring FRG input into international ATC systems, (2) supporting domestic development of smaller aircraft and helicopters, (3) solving ATC problems, and (4) providing competent advice to the civil-aviation community. Specific projects in advanced avionics (fiber-optic ring-laser gyros, cockpit equipment, obstacle-warning radars, and weight/center-of-gravity measurement systems), ATC (precision DME for the ICAO MLS), and flight-control (for the A-300, A-310, and A-320) are described in more detail and illustrated with photographs. T.K.

A88-10678#
THE IMPORTANCE OF MODERN POSITIONING AND NAVIGATION TECHNOLOGY FOR ATC [BEDEUTUNG MODERNER TECHNOLOGIE FUER ORTUNG UND NAVIGATION IN DER FLUGSICHERUNG]
J. LISCHKA (Bundesanstalt fuer Flugsicherung, Frankfurt am Main, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 181-186. In German.

The developmental history and current status of ATC technology in the FRG are examined in a general overview. Topics addressed include the fundamental purposes of ATC, the goals outlined for the FRG ATC services in 1954, the capabilities of the present state-of-the-art air-situation display system DERD-MC, and the problems encountered in gaining public and user acceptance of new advanced systems. Consideration is given to the greater susceptibility of complex systems to total (rather than partial) breakdown, the introduction of MLS, microprocessor-based speech and data transmission, advanced radars and radar displays, and the use of simulators in ATC training. T.K.

A88-10680#
DEVELOPMENT AND TRENDS IN RADIO POSITION FINDING [ENTWICKLUNGEN UND TRENDS DER FUNKORTUNG]
MANFRED BOEHM (Standard Elektrik Lorenz AG, Stuttgart, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 230-249. In German. refs

The history and fundamental principles of radio position-finding (RPF) are reviewed, with an emphasis on currently available technology and development trends. Consideration is given to basic methods for avoiding measurement errors due to reflections; the problems posed by range limitations; the transition from analog to digital RPF technology; satellite RPF systems; the shift from ground-based to onboard RPF computers; the characteristics of specific RPF systems; and the trend toward integrated systems combining communication, navigation, and surveillance functions. Extensive diagrams, drawings, photographs, and tables listing RPF-system features are provided. T.K.

A88-10682#
INERTIAL NAVIGATION - TECHNOLOGICAL STATUS AND DEVELOPMENT TRENDS [TRAEGHEITSNAVIGATION - STAND DER TECHNIK UND ENTWICKLUNGSTENDENZEN]
B. STIELER (DFVLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 262-289. In German. refs

The history and current status of inertial navigation systems (INSs) are surveyed, with an emphasis on developments in the FRG, and illustrated with extensive diagrams, drawings, and photographs. Topics addressed include the invention and further refinement of the gyrocompass and INSs based on it, state-of-the-art strapdown systems, the impact of the ring-laser gyro (RLG) on modern INS technology, efforts to reduce the size of RLGs, and the fiber-optic gyro as an alternative to the RLG. Consideration is given to proposed designs for digital-output optical accelerometers; applications of INS technology to specialized measurement problems; and the mechanical configurations of advanced platform-type INSs for long-term autonomous navigation, geodesy, and surveying. T.K.

A88-10684#
HYBRID POSITIONING AND NAVIGATION SYSTEMS - TECHNOLOGICAL STATUS AND DEVELOPMENT TRENDS IN POSITION-FINDING AND NAVIGATION PROCEDURES [HYBRIDE ORTUNGS- UND NAVIGATIONSSYSTEME - STAND DER TECHNIK UND ENTWICKLUNGSTENDENZEN VON ORTUNGS- UND NAVIGATIONSVERFAHREN]
K. HURRASS (DFVLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 323-337. In German. refs

The fundamental principles of Kalman digital filtering are explained, and the application of Kalman filters to different types of advanced integrated navigation systems is described and illustrated with diagrams and graphs. The advantages of combining the short-term accuracy and steady response of onboard navigation systems with the long-term accuracy of radio or satellite positioning systems in an integrated system are discussed; the mathematical derivation of Kalman filters is shown; the basic application techniques are outlined; and examples in air, land, and ship navigation are presented. T.K.

A88-10687#
AUTONOMOUS ONBOARD COLLISION AVOIDANCE FOR AIRCRAFT AND SHIPS [BORDAUTONOMER KOLLISIONS-SCHUTZ IN LUFTFAHRT UND SCHIFFAHRT]
PETER FORM (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 389-397. In German. refs

The current development status of onboard collision-warning systems for ships and aircraft is surveyed, and the results of recent numerical simulations of the TCAS II secondary-radar/transponder system for aircraft are summarized. Topics addressed include the different requirements of marine and air traffic, the international standard Automated Radar Plotting Aid for ships, and the basic operating principles and range of applicability of TCAS II. The simulation results for typical heavy traffic conditions (such as those encountered over Britain and the FRG) indicate that TCAS II would give a traffic advisory once every 6.5-8 flight hours (or 0.2 ATC hours) and a resolution advisory about once every 15 flight hours (or 1 ATC hour). The potential advantages of a TCAS-type system for ships are considered. T.K.

A88-10688#
DEVELOPMENT STUDIES OF A EUROPEAN DATA NETWORK FOR ACQUISITION, PROCESSING, AND DISPLAY OF AIR-TRAFFIC DATA [ANSAETZE ZU EINEM EUROPAEISCHEN DATENVERBUNDNETZ ZUR ERFASSUNG, VERARBEITUNG UND DARSTELLUNG VON LUFTVERKEHRSDATEN]
HANSJUERGEN F. VON VILLIEZ (Eurocontrol, Maastricht, Netherlands) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 418-427. In German.

A prototype data network developed as part of a Eurocontrol/FRG/Benelux program to facilitate the international exchange of ATC radar data is described. The Radar Data Interchange Network (Radin) is designed to link the civilian ATC centers at Bremen, Duesseldorf, Brussels, Amsterdam, and Maastricht and the Dutch and Belgian military ATC centers, providing real-time flexible-format access to a wide range of information from hardware of different generations. When implemented, Radin should greatly reduce the need for verbal coordination of the transfer of ATC between neighboring centers. Plans call for gradual implementation in five phases, using the integration network structure and Common ICAO Data Interchange Network protocols for the data transmission. T.K.

A88-10728
FAST STABLE SOLUTION OF A DISPERSION EQUATION OF LINEAR FILTERING [BYSTROE USTOICHIVOE RESHENIE DISPERSIONNOGO URAVNENIIA LINEINOI FIL'TRATSII]
A. N. KOROLLEV, ED. Radiotekhnika (ISSN 0033-8486), June 1987, p. 21-23. In Russian.

The paper examines the solution of a dispersion equation for the filtering of the primary parameters, i.e., the delay time and Doppler-frequency difference, in a four-position flight-vehicle radar system. It is shown that, for short periods of time, it is possible to increase the speed of the solution by 3-9 times without decreasing the accuracy. B.J.

A88-10874
FLIGHT DIRECTOR GUIDANCE FOR MLS
JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 7, Sept. 1987, p. 30-35.

The advantages of using MLS compared to the instrument landing system are: easier installation of the system; more channels; improved glide slope and azimuth; and increased flexibility. The flexibility provided by the multiple, curved three-dimensional approach paths of MLS is evaluated using pilot aircraft simulations. Flight director steering commands and path guidance were computed for a straight-in approach and three complex curved paths (offset, hook, and river) using three different algorithms. The algorithms computed lateral deviation based on: (1) capturing the next straight path, (2) based on a continuous curved path, and (3) based on ground speed and nominal bank angle. If flight director steering commands were used, all three forms of guidance could be used to fly any of the curved approach paths and flight director guidance reduced all path tracking errors. A diagram of the arrangement of the flight instruments and profiles of different types of guidance are presented. I.F.

A88-12474
THE CONFLICT RESOLUTION PROCESS FOR TCAS II AND SOME SIMULATION RESULTS
R. L. FORD (Royal Signals and Radar Establishment, Malvern, England) Journal of Navigation (ISSN 0373-4633), vol. 40, Sept. 1987, p. 283-302; Discussion, p. 302, 303. Research supported by the Civil Aviation Authority. refs

The principles underlying the Traffic Alert and Collision Avoidance System which was designed to resolve conflicts between airborne aircraft are discussed. Simulation results obtained with a fast-time computer model for random traffic are presented. They include statistics on miss distance and warning time for a simple traffic pattern. K.K.

A88-12733
REAL-TIME RECONNAISSANCE - AN ENGINEERING PERSPECTIVE
NORMAN W. BOESE and ANTHONY S. CLARK (Control Data Corp., Minneapolis, MN) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 28-32.

New electrooptical (EO) systems are currently being developed for tactical reconnaissance. To ensure that these systems can be developed within budget, it is essential that operational and technical requirements be developed together. This paper is an attempt at defining technical capabilities and costs in terms of operational requirements. Author

A88-12737
SYNCHRONIZING VIDEO SIGNALS TO STANDARD IRIG TIME CODES
LESTER TURNER (Video DataCom, Fountain Valley, CA) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 49-54.

An IRIG code/video signal synchronizer has been developed that generates EIA RS 170/RS170A/RS330 and NTSC compatible video synchronizing signals that are directly referenced to an input standard IRIG Type A or B modulated serial time code. When an IRIG modulated serial time code is introduced into the synchronizer, detection of the beginning of a time code frame initiates generation of the first field in the first frame (00) in the output video signal. The video synchronizing signals are phase locked to the input time code modulated carrier. A very stable crystal controlled oscillator time base in the synchronizer insures that the phase lock loop is jitter free and video signal output continues even if the input time code is removed. The output composite video synchronizing signal is able to synchronize the operation of different video signal sources and directly references their video output signals to the available IRIG modulated serial time code. Author

A88-13087#
A HYBRID NAVIGATION SYSTEM WITH GPS
TORU TANABE and MASATOSHI HARIGAE Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 8-14. In Japanese. refs

The design, characteristics, and performance of a hybrid navigation system using the GPS are described. The designs of the GPS-INS, GPS-STAR, and GPS-INS-STAR systems are

discussed and compared. The performance of the GPS receiver with a digital signal processor is examined. S.H.

A88-13088#
CIVIL AVIATION APPLICATION OF THE GLOBAL POSITIONING SYSTEM (GPS) AND ITS ISSUES
KOICHI KIMURA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 15-21. In Japanese. refs

Recent trends in the utilization of the GPS for civil aviation are reviewed. Attention is given to GPS precision, the user equivalent range, and the probable error. The relationship between satellite radio-position determination and the GPS is examined. S.H.

A88-13090#
GPS/INS HYBRID NAVIGATION FOR AIRCRAFT
NAOHIRO YAMASHITA and HIROSHI KIJIMA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 29-36. In Japanese. refs

The efficiency of the GPS/INS hybrid navigation system is evaluated by computer simulation. In the GPS the error was found to increase with maneuvering of the aircraft, while in the INS the error was found to increase with time. Future prospects for the hybrid system are assessed. S.H.

A88-13093#
GPS RECEIVERS FOR AIR NAVIGATION
CHOGO SEKINE Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 51-56. In Japanese.

The paper describes the design and characteristics of the GPS receiver for air navigation using the C/A code. Various functions of the GPS receiver are considered, including the single-channel sequence, the high-speed single-channel sequence, and the five-channel sequence. S.H.

A88-13094#
FLIGHT TEST RESULTS FOR A GPS RECEIVER IN A HELICOPTER AND A BUSINESS AIRCRAFT
TOSHIMICHI OKITA and AKIRA IGA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 57-62. In Japanese. refs

Flight test results for the four-channel GPS receiver in helicopters and turboprop business aircraft are reported. No effect of the helicopter rotary wing on the GPS receiver was observed. A block diagram of the receiver is presented. S.H.

N88-10025# European Space Agency, Paris (France).
TEST EQUIPMENT WITH FIBER OPTIC DATA BUS AND LASER GYRO STRAPDOWN SYSTEM LTN-90 FOR THE HELICOPTER BO-105
HANS-JUERGEN HOTOP and HANS-PETER ZENZ Apr. 1987 49 p Transl. into ENGLISH of Aufbau einer Messtechnik mit Lichtleitfasern und einem Laserkreisel-Strapdown-System LTN-90 im Hubschrauber BO-105 (Brunswick, Fed. Republic of Germany, DFVLR) 1985 Original language document announced as N86-17333
(ESA-TT-1038; DFVLR-MITT-85-10; ETN-87-90669) Avail: NTIS HC A03/MF A01; original report in German available from DFVLR, Cologne, West Germany DM 19

The measuring instruments with a MUDAS interface system for flight-testing navigation systems in the helicopter BO-105 are described. The bit-serial bus was constructed using fiber optics. The reference data from a laser gyro strapdown navigation system were corrected by application of optimal filter techniques and external measurements. The results of testing the overall system are presented, and the accuracy of the development of the reference trajectory compared with the data of the laser radar PATS is explained with reference to a test flight. ESA

N88-10784 Alabama Univ., Huntsville.
GLOBAL POSITIONING SATELLITE-BASED AUTOMATIC LANDING SYSTEM AND WIND ESTIMATED FEEDBACK FOR THE AH-64 HELICOPTER Ph.D. Thesis
ABDOLLAH HOMAIFAR 1986 288 p
Avail: Univ. Microfilms Order No. DA8713429

A real time simulation of a helicopter is used to investigate the Global Positioning Satellite guidance and control during a fully automatic spiral descent and landing flare maneuver in the presence of crosswind and turbulence. The spiral descent offers a landing pattern, restricted in area, which is useful near congested airports, for both civil and military operations. It was shown that combined optimal estimation and control techniques are feasible for reduction of spiral descent guidance errors. The optimal estimation is accomplished using an extended Kalman filter, resulting in an estimated state of an aircraft and crosswind. This estimated state constitutes an input to an optimal linear regulator. Improvements in accuracy are made by adding an altimeter and body mounted accelerometers. Modifications of the steady-state, reduced-order Kalman filter are described which provide a satisfactory estimator in such cases. The results of applying these techniques to the design of an estimator for aircraft position and crosswind are presented. A design of an optimal controller for spiral descent and landing flare with augmented crosswind is also included. The linear optimal regulator theory is utilized to derive state feedback gain for guidance and control. The estimator and controller performances are verified using a Monte Carlo simulation. Dissert. Abstr.

N88-10810# Carleton Univ., Ottawa (Ontario). Dept. of System and Computer Engineering.
AN EXPERT SYSTEM FOR AIRCRAFT CONFLICT RESOLUTION IN DENSE AIRSPACES
B. A. BOWEN *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 13 p Aug. 1987 Sponsored by Transport Canada
Avail: NTIS HC A07/MF A01

A hybrid, knowledge-based system is described which provides advice to air traffic controllers on the optimal tactics for resolving predicted aircraft conflicts. The overall functional architecture is described which has both computational algorithms and rule bases containing the knowledge and experience of controllers in the air traffic environment. The system is designed to replicate the way a controller might react to a predicted conflict. It responds to conflict predictions with resolution advice, which depends on both formal rules and on heuristics obtained from controllers. Author

N88-10815# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.
A RULE-BASED SYSTEM FOR ARRIVAL SEQUENCING AND SCHEDULING IN AIR TRAFFIC CONTROL
U. VOELCKERS *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p Aug. 1987
Avail: NTIS HC A07/MF A01

A rule based system is presented that is designed to assist human controllers in efficiently merging high density inbound traffic into congested airports. The rationale for the design of a rule based system and the critical requirements for the development of a rule based system for application to air traffic control are discussed. The system uses the OPS5 production system and is programmed in FRANZ LISP with embedded C functions. The system still has limited capabilities. Author

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A88-10049
FLIGHT CHARACTERISTICS OF AIRCRAFT WITH GAS-TURBINE ENGINES [LETNYE KHARAKTERISTIKI SAMOLETOV S GAZO-TURBINNYMI DVIGATELIAMI]
BORIS VASIL'EVICH KALINICHENKO Moscow, Izdatel'stvo Mashinostroenie, 1986, 144 p. In Russian. refs

Methods are presented for the in-flight determination of the performance characteristics of turbojet and turboprop aircraft. Attention is given to measurements of aircraft speed, flight altitude, pressure, and Mach number; determination of aerodynamic corrections and their physical meaning; generalized maneuverability characteristics, and determination of the speed of turbojet and turboprop aircraft by the acceleration method. The discussion also covers the equivalent height and differential correction methods for determining the speed of horizontal flight under given conditions, maximum flight distance and time, and takeoff and landing characteristics of turbojet and turboprop aircraft. V.L.

A88-10655
NEW SOVIET COMMERCIAL AIRLINERS [NEUE SOWJETISCHE VERKEHRSFLUGZEUGE]
FRITZ SEIDLER (Hochschule fuer Verkehrswesen, Dresden, German Democratic Republic) Technisch-oekonomische Information der zivilen Luftfahrt (ISSN 0232-5012), vol. 23, no. 3, 1987, p. 89-100. In German.

Significant tendencies in the development of commercial aviation construction are reviewed, and new types of Soviet commercial airliners are described. Advances that have recently been made in the distance of travel, load capacity, and flight velocity of commercial airliners are addressed. The aircraft considered include the IL-114, intermediate distance Tu-204, and the long-distance IL-96-300. New types of Soviet helicopters and hybrid aircraft are also discussed. C.D.

A88-10656
THE FOURTH GENERATION OF TL COMMERCIAL AIRCRAFT [UEBER DIE 4. GENERATION DER TL-VERKEHRSFLUGZEUGE]
OTTO POLACEK (Ceskoslovenska Vedeckotechnicka Spolecnost, Prague, Czechoslovakia) Technisch-oekonomische Information der zivilen Luftfahrt (ISSN 0232-5012), vol. 23, no. 3, 1987, p. 103-107. In German. refs

Advances in commercial aircraft that are represented by the fourth generation of TL airliners are discussed. The requirements imposed on this generation of aircraft are summarized, and the use of quantitative modeling in the development of the third and fourth generation of the TL aircraft is reviewed. The development of new constructional technologies, the use of artificial materials and composites, and the economics of air travel are considered. C.D.

A88-10659
THE WILL TO EUROPEAN UNITY AS EXEMPLIFIED BY A320 [WILLE ZUR EUROPAEISCHEN EINHEIT AM BEISPIEL A320]
JEAN ROEDER Luft- und Raumfahrt (ISSN 0173-6264), vol. 8, 3rd Quarter, 1987, p. 38, 40, 42-44 (5 ff.). In German.

The roles of various European governments in the development of the A320 aircraft are discussed. The technology of the aircraft is briefly considered, and the A320's profile is compared with that of the A310. The aircraft's flight control surfaces, architecture, flight envelope, flight control system, load alleviation system, side-stick controller, approach configuration, and Integrated Air Data and Inertial System are shown and discussed. The aircraft's automatic monitoring and 'ministick' are addressed. C.D.

A88-10675
B-1B COMBINES BRISK LOW-ALTITUDE HANDLING, MORE CAPABLE AVIONICS
DAVID M. NORTH, BRUCE D. NORDWALL, and WILLIAM B. SCOTT Aviation Week and Space Technology (ISSN 0005-2175), vol. 127, Sept. 14, 1987, p. 54, 55, 58 (9 ff.).

The performance of the B-1B is evaluated. The systems and capabilities of the aircraft are described. Particular consideration is given to its low-altitude performance, landing characteristics, in-flight refueling capabilities, and the offensive electronic systems. The engine start and initial taxi, the ride of the aircraft, and its internal navigation system are discussed. I.F.

A88-10871
STARTING SYSTEM FOR COLD WEATHER
JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 7, Sept. 1987, p. 11-14.

The use of high pressure pneumatic start systems for military tactical aircraft operating in extremely cold weather environments is examined. There are two methods for implementing a pneumatic starting system: (1) an impingement start system and (2) a pressurized air start system. The pressurized air start system is compared to electric and hydraulic starting systems in terms of weight and volume. It is observed that the pressurized air start system can be utilized without causing weight problems, but with volume penalties. The size of the air pressure vessel can be reduced by increasing the system pressure; a system pressure of 4000 psi was estimated as optimum for the start system. Proposed future improvements in pneumatic systems, in particular weight and volume reductions, are discussed. I.F.

A88-10873
AIRCRAFT TYRES
STUART BIRCH Aerospace Engineering (ISSN 0736-2536), vol. 7, Sept. 1987, p. 24-27.

The use of radial tires on aircraft is examined. The advantages provided by using aramid instead of nylon belting in the tires are discussed. The problems encountered using radials on aircraft are the deflection rate of the section height and the technical difficulties of developing a thin-walled radial. The average life for a radial tire is 200 landings; it will provide weight savings of 10-15 percent, require fewer tire changes, run cooler, and reduce foreign object damage. The tires will be useful for about 1200-2000 landings, but will require 10-12 retreads; the procedures for retreading radials are described. I.F.

A88-10875
HTTB - THE ULTIMATE TEST BED
JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 7, Sept. 1987, p. 58-61.

The design and systems of the High Technology Test Bed (HTTB), which is a modified L-100-20, are described. The HTTB was designed as an airborne test platform that would provide a vehicle for integrated testing of systems to investigate STOL performance enhancements, survivability improvements, and advanced flight station designs. Consideration is given to the HTTB's structural extensions to the vertical and horizontal stabilizers, the spoiler system, the dual rotary electromechanical actuators, and the electronic system. The HTTB is applicable for evaluating navigation systems and advanced cockpit displays, and has been utilized to test the wing-mounted SAMSON (special avionics mission strap-on now) pod. A diagram of the aircraft is provided. I.F.

A88-10876
THE ANTONOV AN-74 BRINGS HIGH TECH TO LOW TEMPERATURES
MARK LAMBERT Interavia (ISSN 0020-5168), vol. 42, Sept. 1987, p. 907-909.

The design of the An-74, which was developed for support of all types of operations in extreme low temperatures, is described. The An-74 fuselage is 1.5 m longer than that of the An-72; the gross weight is 1500 kg greater than that of the An-72; the thrust

of the turbofans is 63.7 kN each; and cruising speed is 705 km/hr. The aircraft has a maximum passenger capacity of 52 and can carry a maximum payload of 10,000 kg. The flight control/navigation and flight characteristics, such as upper surface blowing system and speeds at takeoff, are examined. I.F.

A88-11195
THE USE OF WIND TUNNEL DATA IN THE DESIGN OF RADIO CONTROLLED CONTEST MODEL SAILPLANES
MARTIN SIMONS (Adelaide, University, Australia) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 20.1-20.62. refs

The tasks which a model sailplane must accomplish during a championship contest are reviewed, and the effects of changing the airfoil section and varying other important parameters pertaining to the performance of model sailplanes are mathematically investigated using wind tunnel data. Taper effects, aspect ratio effects, span effects, and the effects of flap modifications are considered. Typical sailplane dimensions and the use of wind tunnels to obtain data about airfoils are also reviewed. C.D.

A88-12412
COMPOSITE MATERIALS IN ROTORCRAFT
WALTER SONNEBORN (Bell Helicopter Textron, Inc., Fort Worth, TX) Vertiflite (ISSN 0042-4455), vol. 33, Sept.-Oct. 1987, p. 10-17.

The present evaluation of state-of-the-art helicopter and tilt-rotor aircraft structural design development notes that military rotorcraft development programs have led to virtually all-composite airframes, using highly automated composite manufacturing techniques that improve composite structures' cost-effectiveness. The applicability of these technologies throughout the helicopter manufacturing industry is discussed. Attention is given to the development status of thermosetting fiber/epoxy materials in such applications as the primary structure and the rotor hub of the V-22 Osprey military tilt-rotor aircraft. O.C.

A88-12413
COMPOSITES TECHNOLOGY IN ARMY AVIATION
JAMES P. WALLER (U.S. Army, Aviation Applied Technology Directorate, Fort Eustis, VA) Vertiflite (ISSN 0042-4455), vol. 33, Sept.-Oct. 1987, p. 18-24.

U.S. Army Aviation R&D programs in advanced helicopter structures technology have been instrumental in the development of rotorcraft applications of composite materials. Attention is given to the development status of advanced composite materials in rotor systems, propulsion components and drivetrains, airframes, and landing gears. In one case, the evaluation of composite manufacturing methods' potential for the reduction of construction costs led to the design and fabrication of the UH-60 helicopter's transition section, which demonstrated a 30-percent cost reduction. The wholesale commitment to composites came in the wake of the subsequent Advanced Composite Air Frame Program, which demonstrated improvements in structural crashworthiness as well as cost and weight savings. O.C.

A88-12645
PREPARE FOR THE 21ST CENTURY - THE 1987 ALEXANDER A. NIKOLSKY LECTURE
J. M. DREES American Helicopter Society, Journal (ISSN 0002-8711), vol. 32, July 1987, p. 3-14. refs

Helicopter, X-wing, and tilt-rotor VTOL aircraft configurational and component technology development trends are projected into the 21st century, in order to evaluate the prospects for speed enhancement, maneuver envelope expansion, range extension, mission complexity and payload improvement, and ease of operation in a variety of applications. Attention is given to rotary wing wake/fixed lifting surface aerodynamic interference effects in hover and cruise regimes. Variable turbomachine blading in turboshaft engines is recommended as a way of minimizing fuel consumption in cruise and furnishing auxiliary propulsion for dash speeds. Transonic capabilities are judged to be feasible in next-generation aircraft. O.C.

A88-13081#
ADVANCED COMPOSITE HORIZONTAL STABILIZER FOR NEXT-GENERATION COMMERCIAL AIRCRAFT
SAKAE YOKOTA and MAKOTO HIRAHARA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 608-614. In Japanese. refs

The experimental design of an advanced composite horizontal stabilizer for next-generation commercial aircraft carrying 150 passengers is described, and its structural characteristics are investigated. The spar structure has a multistringer design while the outer panel has an integral skin design. Based on the FAR Part 25 design standard, the stabilizer uses a graphite/epoxy composite. S.H.

A88-13085#
SOME TOPICS ON AIRCRAFT LANDING GEAR DESIGN
HIROAKI NAKAMURA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 395, 1986, p. 647-649. In Japanese.

Problems in the design of aircraft landing gear are described. Structural design for weight and cost reduction of the landing gear is considered along with the general concept of landing-gear design evaluation. The airframe/landing-gear weight ratio is considered. S.H.

N88-10026*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
HIMAT FLIGHT PROGRAM: TEST RESULTS AND PROGRAM ASSESSMENT OVERVIEW
DWAIN A. DEETS, V. MICHAEL DEANGELIS, and DAVID P. LUX Jun. 1986 30 p
(NASA-TM-86725; H-1283; NAS 1.15:86725) Avail: NTIS HC A03/MF A01 CSCL 01C

The Highly Manueverable Aircraft Technology (HiMAT) program consisted of design, fabrication of two subscale remotely piloted research vehicles (RPRVs), and flight test. This technical memorandum describes the vehicles and test approach. An overview of the flight test results and comparisons with the design predictions are presented. These comparisons are made on a single-discipline basis, so that aerodynamics, structures, flight controls, and propulsion controls are examined one by one. The interactions between the disciplines are then examined, with the conclusions that the integration of the various technologies contributed to total vehicle performance gains. An assessment is made of the subscale RPRV approach from the standpoint of research data quality and quantity, unmanned effects as compared with manned vehicles, complexity, and cost. It is concluded that the RPRV technique, as adopted in this program, resulted in a more complex and costly vehicle than expected but is reasonable when compared with alternate ways of obtaining comparable results. Author

N88-10027# LTV Missiles and Electronics Group, Dallas, Tex. Missiles Div.
DESIGN PRINCIPLES AND PRACTICES FOR IMPLEMENTATION OF MIL-STD-1760 IN AIRCRAFT AND STORES Final Report, Jul. - Dec. 1986
D. E. LAUTNER, A. J. MAREK, W. M. DRUM, and R. R. FERNANDEZ Jun. 1987 432 p
(Contract N60530-85-C-0091)
(AD-A183724; REPT-3-52110-6R-128) Avail: NTIS HC A19/MF A01 CSCL 01C

The trends in weapon system designs (aircraft and stores) has resulted in a growing concern over the general proliferation of aircraft-to-store electrical interfacing requirements and the resulting high cost to achieve interoperability between aircraft and stores. MIL-STD-1760 was prepared to reduce the aircraft/store electrical integration problem by specifying a standard electrical interface between aircraft and stores. The standard electrical interface is based on recognized trends in store management

systems which use serial digital transmission for control, monitor, and release of stores. This report deals with the interoperability requirements as described in MIL-STD-1760 and is intended to be an aid to understanding and meeting the requirements for both current and future weapon systems. In general, this report provides the following: (1) An overview of MIL-STD-1760 requirements, exclusions and future growth provisions. (2) Detail design considerations applicable to the Aircraft Station Interface (ASI). (3) Detail design considerations applicable to the Mission Store Interface (MSI). (4) Aircraft/Store Physical Design Considerations. (5) A commentary on the requirements in MIL-STD-1760. GRA

N88-10028# National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.
PROBLEM AND SOLUTION FORMULATIONS FOR THE GENERATION OF 3D BLOCK-STRUCTURED GRIDS
J. W. BOERSTOEL 3 Mar. 1986 16 p Presented at the 1st International Conference on Numerical Grid Generation in Computational Fluid Dynamics, 14-17 Jul. 1986, Landshut, Fed. Republic of Germany
(NLR-MP-86020-U; B8701063; ETN-87-90825) Avail: NTIS HC A03/MF A01

The technical concepts of a method for the generation of 3D block-structured grids are presented. The generation process is decomposed in four steps: topological block decomposition; geometrical modeling of known and unknown coordinate functions; grid initialization by multilinear transfinite interpolation; and elliptic cell partitioning. The elliptic method is based on simple partial differential equations representing locally decoupled ID stretchings followed by 3D rotations. Mesh-size and smoothness control occurs with user-provided weight functions that are inversely proportional to desired mesh sizes. Test results are shown. ESA

N88-10029# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Abteilung Flugzeugsteuerung und- Regelung.
AN OBSERVER APPROACH TO THE ESTIMATION OF HELICOPTER AIRSPEED Ph.D. Thesis - Technische Univ.
BURKHARD MUELLER Apr. 1987 152 p In GERMAN; ENGLISH summary
(DFVLR-FB-87-13; ISSN-0171-1342; ETN-87-90597) Avail: NTIS HC A08/MF A01; DFVLR, Cologne, West Germany DM 52.50

Difficulties in measuring the airspeed of helicopters because of low dynamic pressures in the low airspeed regime and because of the rotor downwash influencing the flow field around the fuselage are reviewed, and a nonlinear state observer for the estimation of helicopter airspeed is described. Uncertainties in the models of helicopter dynamics affect the method. A procedure that allows a simple adaptation of the models to real conditions is presented. It is shown that parameter sensitivity can be reduced and the low static stability regime can be handled. The results are verified by flight tests. ESA

N88-10787# Loughborough Univ. of Technology (England). Dept. of Electrical and Electronic Engineering.
DECOUPLING AND STABILIZATION OF SPEED AND HEIGHT IN F4 PHANTOM AIRCRAFT USING OUTPUT FEEDBACK M.S. Thesis
J. M. HAMMER 1987 176 p
(ETN-87-90926) Avail: NTIS HC A09/MF A01

The equations of motion of an F4 aircraft are numerically evaluated for straight and level flight at Mach 1.1 at sea level. The inputs of the system are speed demand and height demand; the outputs are speed and height, to be stabilized and decoupled using output feedback and cascade compensation. The algebraic approach, the root locus approach, and the frequency response approach are compared. The first two have considerable drawbacks, the major one being the necessity to specify exactly the pole positions in the stabilized aircraft when a large range of pole positions is acceptable. The frequency response approach, however, provides a logical and methodical means of arriving at solutions for the compensation matrix elements, with the stability of the aircraft response being clearly displayed on a Nichols Chart. ESA

N88-10788*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
FLIGHT RESEARCH AT NASA AMES RESEARCH CENTER: A TEST PILOT'S PERSPECTIVE
G. WARREN HALL Sep. 1987 13 p
(NASA-TM-100025; A-87323; NAS 1.15:100025) Avail: NTIS HC A03/MF A01 CSCL 01C

In 1976 NASA elected to assign responsibility for each of the various flight regimes to individual research centers. The NASA Ames Research Center at Moffett Field, California was designated lead center for vertical and short takeoff and landing, V/STOL research. The three most recent flight research airplanes being flown at the center are discussed from the test pilot's perspective: the Quiet Short Haul Research Aircraft; the XV-15 Tilt Rotor Research Aircraft; and the Rotor Systems Research Aircraft. Author

N88-10812# Royal Aircraft Establishment, Farnborough (England).
TOWARDS THE UNMANNED COCKPIT
BRIAN ELLIS *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p Aug. 1987
Avail: NTIS HC A07/MF A01

Trends in air warfare make the development of autonomous unmanned aircraft necessary. Advances in intelligent knowledge-based systems (IKBS) and in computing technology will make it possible. The case for unmanned aircraft and their probable evolution is made. Some indications are offered of the developments that will be called for in the IKBS themselves and in the computing hardware. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A88-10436
FDAD - A LAB/FIELD TEST TOOL
BRUCE FENCHEL and JOSEPH AUER (Northrop Corp., Defense Systems Div., Rolling Meadows, IL) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 2, Sept. 1987, p. 5-7.

Flight Data Analysis and Display, FDAD, is a hardware and software tool that permits the monitoring of the hardware and software of a multiprocessor electronic countermeasure, ECM, system in a noninterfering mode. FDAD monitors user-defined memory addresses and hardware lines and displays in real-time the changes to these locations. Data is also stored for subsequent analysis and display. This tool allows developers to identify the operating characteristics of an extremely complex and fast system with the assurance that the instrumentation does not alter the true performance of that system. Author

A88-10679#
THE IMPACT OF MODERN TECHNOLOGY ON AIRCRAFT AVIONICS EQUIPMENT [AUSWIRKUNG MODERNER TECHNOLOGIE IN DER AVIONIK-AUSRUESTUNG VON FLUGZEUGEN]
DIETER REICHOW (Deutsche Lufthansa AG, Hamburg, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 219-228. In German.

The recent developmental history and current status of transport-aircraft avionics are reviewed and illustrated with extensive diagrams, graphs, and flow charts. Topics addressed include the emphases on increased safety and flight capability, greater automation, and reduced fuel consumption in the 1970s; the goals of modern avionics design (crew and component redundance, reduced or delayable corrective measures, and transparence); and the application of digital systems to achieve these goals in the 1980s. Consideration is given to cabin electronics, data links, fault-tolerant systems, and onboard electronic documentation. T.K.

A88-10685#
OPTIMAL INFORMATION PROCESSING FOR SENSORS AND SENSOR SYSTEMS - THE CASE OF RADAR SENSORS [OPTIMALE INFORMATIONSAUFBEREITUNG FUER SENSOREN UND SENSORSYSTEME AM BEISPIEL RADARSENSOREN]
PETER SCHMITT (AEG AG, Ulm, Federal Republic of Germany) (Deutsche Gesellschaft fuer Ortung und Navigation, Navigationstagung ueber moderne Technologie in Ortung und Navigation, Duesseldorf, Federal Republic of Germany, May 6-8, 1987) Ortung und Navigation (ISSN 0474-7550), vol. 28, no. 2, 1987, p. 356-370. In German.

Data-processing architectures (DPAs) for hybrid onboard air-navigation systems are examined analytically. The advantages of combining different types of optical and radar sensors are reviewed, and DPAs in which fast, dedicated preprocessors connected directly to the sensor transmit reduced data to slower, more flexible main processors are described in detail for the case of primary radar sensors. Overall hybrid DPAs in which data from different sensors are combined directly after the preprocessor and after main-processor treatment are compared, taking the impact of advances in semiconductor technology into account. Extensive diagrams and flow charts are provided. T.K.

A88-12569#
TOWARDS THE DESIGN OF AN INTELLIGENT AEROSPACE SYSTEM
M. EL-ARABATY (Military Technical College, Cairo, Egypt) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 318-328. refs
(AIAA PAPER 87-2844)

In dense multiple aircraft surveillance environments, radar tracking of maneuvering aircraft is difficult due to the problem of discriminating against nearby target reports in the correlation process. Three main problems are given: the multitarget tracking, the probability of detection, and the assignment algorithm operating in a dense target environment. The key performance characteristics of the designed algorithm is the flexibility for adaption to other tracking environments and incorporation into existing tracker designs. A new approach is given for the structure of a rule-based aerospace expert system. Author

A88-12574#
EXPERT SYSTEM CONTROL FOR AIRBORNE RADAR SURVEILLANCE
ROBERT J. MCKENZIE and DAVID G. MULLENS (Boeing Aerospace Co., Seattle, WA) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 353-357. refs
(AIAA PAPER 87-2854)

The paper describes the application of an expert system to the control of a phased array radar. The goal of the research was to investigate operational radar control strategies which demonstrate gain in radar performance. A test bed, consisting of a prototype expert system controller and a phased array radar simulator, was built to conduct experimental runs of surveillance scenarios. The test bed was incrementally developed as a hybrid between conventional algorithmic programs and an expert system, taking advantage of the best features of each. Attention is focused on a description of the test bed and a discussion of advanced AI development environments and expert system run-time performance. Author

A88-12655
AIRSPEED MEASUREMENT WITH A CO2 LIDAR
BERTRAND MORBIEU and JACQUES MANDLE (Crouzet, S.A., Division Aerospatiale, Valence, France) IN: Contemporary optical instrument design, fabrication, and testing; Proceedings of the Meeting, Innsbruck, Austria, Apr. 17, 18, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 220-224. Research sponsored by the Ministere de la Defense Armee de l'Air and DRET. refs

A laser Doppler technique has been developed since 1978 to provide aircraft air data calibration. A CW CO2 laser sensor performs a coherent detection of the light scattered by the aerosols sustained in the air. The instrument has successfully flown in the vibrating environments of helicopter and aircraft. Author

A88-12728
AIRBORNE RECONNAISSANCE X; PROCEEDINGS OF THE MEETING, SAN DIEGO, CA, AUG. 19, 20, 1986
PAUL HENKEL, ED. (General Dynamics Corp., Saint Louis, MO) and FRANCIS R. LAGESSE, ED. Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 694), 1987, 176 p. For individual items see A88-12729 to A88-12751.
(SPIE-694)

The present conference on airborne reconnaissance considers topics in primary data collection system design, the management of reconnaissance sensor data, reconnaissance systems' research and development status, and the achievement of real-time intelligence. Attention is given to airborne minefield detection, forest fire detection, high speed transform image compression, data link design tradeoffs for electrooptical reconnaissance systems, and airborne reconnaissance sensor pods. Also discussed CCD millimeter-wave imaging sensors, an advanced CCD reconnaissance detector, recent developments in IR data processing, and the requirements of low altitude reconnaissance. O.C.

A88-12731
SENSOR CONTROL/DATA DISPLAY SET (SC/DDS) FOR FILM AND/OR ELECTRO OPTICS (EO)
W. FISHELL and J. RADER (Fairchild Communications and Electronics Co., Germantown, MD) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 14-20.

Recent sensor control development systems, designed for demonstration of Electro Optics (EO) Systems, have required similar control signals as those required for film sensors. From this similarity of interface controls and functions (along with cost considerations) comes the realization that reconnaissance systems of the future must evolve in a modular fashion to produce the

level of sophistication, or complexity, required for each specific mission. Fairchild Communications and Electronics Company has developed an AN/ASQ-197, Sensor Control/Data Display Set (SC/DDS) to control sensors and annotate film in the F/A-18(R) Reconnaissance System. The An/ASQ-197, with its programmability, is the basic building block of this hybrid system of the future, for film and/or EO. This paper presents some of the considerations and features of such a system. Author

A88-12736
MAGNETIC RECORDING FOR NEAR REAL TIME RECONNAISSANCE APPLICATIONS
W. D. KESSLER (Fairchild Weston Systems, Inc., Data Systems Div., Sarasota, FL) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 43-48. refs

The definition of recording for 'near real time reconnaissance' applications is reviewed along with the requirements for a recorder to be used in this application. Next the storage medium (magnetic tape) and its importance is discussed. Following this, the recording technologies available to achieve the required results are presented. Both longitudinal fixed head and helical scan rotary head technologies are considered along with some of their merits and demerits. Finally, a brief look into the future of this storage technology is presented. Author

A88-12740
DATALINK DESIGN TRADE-OFFS FOR ELECTRO-OPTICAL RECONNAISSANCE SYSTEMS
WILLIAM N. WAGGENER (Fairchild Weston Systems, Inc., Data Systems Div., Sarasota, FL) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 70-78.

The design of the datalink for real-time electrooptical reconnaissance systems is a function of many system variables with many conflicting requirements. The datalink design must consider cost and frequency management issues. Sensor data rate has a particularly strong impact on a number of key design parameters. As the data rate increases, RF bandwidth increases forcing the datalink to operate at higher carrier frequencies. With a fixed RF bandwidth constraint, the higher rate decreases anti-jam processing margin, increases cost and generally increases system complexity. With data compression, the bandwidth can be decreased at the expense of an increasing sensitivity to datalink errors. In this paper, the sensitivity of the datalink design to a number of the most important design requirements is examined with particular attention paid to the datalink cost and frequency management issues. Author

A88-12741
AIRBORNE RECONNAISSANCE POD FLIGHT TEST
P. HENKEL (General Dynamics Corp., Fort Worth, TX) and R. STURZ (Recon/Optical, Inc., CAI Div., Barrington, IL) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 80-87.

An account is given of the design features and performance capabilities of a reconnaissance sensor-carrying pod for use by such tactical aircraft as the F-16. The pod design requirements call for not only a minimization of size, weight, and cost, but also the entailment of only minimal aircraft modifications for pod incorporation, and the accomodation of multiple sensor types and combinations of sensors with their associated system components. A rotatable nose compartment is used which allows both vertical and forward oblique photography in high speed low altitude reconnaissance missions that may preclude direct flight over a target site. O.C.

A88-12742
SENSOR CONFIGURATION FOR A SHORT TO MEDIUM RANGE RECONNAISSANCE POD
INGVAR H. JOHANSSON (FFV Aerotech, Linkoping, Sweden) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 88-91.

The GREEN BARON pod is designed and developed specifically for penetrating reconnaissance and for reconnaissance up to medium distance. An Infra Red Line Scanner (IRLS) in combination with a panoramic camera are the main short range sensors, the IRLS as an all weather sensor and the panoramic camera to get horizon to horizon coverage and stereo interpretation. For reconnaissance up to medium distance the choice was a camera with 12 inch focal length. This focal length gives moderate focusing problems when operating over a wide distance range. Influence on performance caused by environment is easier to deal with compared to operating a camera with longer focal length. This paper concentrates on the reasons for choosing a focal length of 12 inches for the pod. Author

A88-12748
IMAGING THROUGH THE ATMOSPHERE FOR AIRBORNE RECONNAISSANCE
N. S. KOPEIKA (Negev, University, Beersheba, Israel) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 132-139. refs

Turbulence, atmospheric background, and aerosol forward scattering MTFs are presented and analyzed with regard to both low elevation rpv and high elevation reconnaissance applications. Turbulence is seen to limit image quality only at very high spatial frequencies where degradation effects are likely to take place anyway as a result of vibrational and diffraction effects. Background and aerosol MTFs limit low spatial frequency contrast as well. However, this can be overcome somewhat by proper selection of imaging wavelength. This analysis can aid in sensor selection for system design from the standpoints of both wavelength selection and sensor resolution. Author

A88-12749
ARGUMENTS FOR ELECTRO-OPTICAL RECONNAISSANCE SYSTEMS
ROBERT L. SKILLEN (Litton Industries, Inc., Itek Optical Systems Div., Lexington, MA) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 140-144.

Electrooptical (EO) digitally-recorded systems for tactical airborne reconnaissance require lower light levels for operation than film-based systems despite their greater haze-penetration capability. EO systems also allow the incorporation of a real-time imagery distribution net allowing all levels of command to see the target simultaneously; this does not jeopardize more careful subsequent study of the digital images obtained. About 10 times greater area can be covered with an EO system by an image interpreter, in comparison to the study of film on a light table. O.C.

A88-12750
SOFTCOPY VERSUS HARDCOPY
PIERRE DEMATHIEU (Matra Technology, Inc., San Jose, CA) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 145-149.

In most ot the existing reconnaissance systems, the film is used as a storage medium. But more and more the photointerpreter processes the film information with the help of digital image displays. As the sensors are more and more digital or at least electronic, the film appears to be just an intermediate step, with many shortcomings. Going into completely digital systems seems to be very promising, but not very easy to do right now in respect to some operational needs. Author

A88-12751
RECENT DEVELOPMENTS IN INFRARED DATA PROCESSING
WILLIAM L. MCCRACKEN (Honeywell, Inc., Electro-Optics Div., Lexington, MA) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 150-157.

The exceptionally great data rates generated by advanced military aircraft IR linescan sensors in low level penetration reconnaissance missions calls for the use of an automated data management system (DMS), if optimum use of onboard sensors by the crew is to be achieved. Attention is presently given to the development status of DMSs, as well as of data recorders and automatic target cuers; all employ VLSI and VHSIC implementations of dense, high speed image processing chips. Progress to date on the algorithms needed to operate the DMS and autocuer hardware is also noted. O.C.

N88-10030*# Battelle Columbus Labs., Ohio.
DIGITAL SYSTEM BUS INTEGRITY Final Report
DONALD ELDREDGE and ELLIS F. HITT Mar. 1987 100 p Prepared in cooperation with Lockheed-Georgia Co., Marietta (Contract NAS2-11853)
(NASA-CR-181446; NAS 1.26:181446; DOT/FAA/CT-86/44)
Avail: NTIS HC A05/MF A01 CSCL 01D

This report summarizes and describes the results of a study of current or emerging multiplex data buses as applicable to digital flight systems, particularly with regard to civil aircraft. Technology for pre-1995 and post-1995 timeframes has been delineated and critiqued relative to the requirements envisioned for those periods. The primary emphasis has been an assured airworthiness of the more prevalent type buses, with attention to attributes such as fault tolerance, environmental susceptibility, and problems under continuing investigation. Additionally, the capacity to certify systems relying on such buses has been addressed. Author

N88-10031# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Abteilung Anthropotechnik und Simulation.
COLOR DISPLAY PROGRAMMING FOR AVIATION
HERMANN WIESNER Nov. 1986 52 p In GERMAN; ENGLISH summary
(DFVLR-MITT-87-03; ISSN-0176-7739; ETN-87-90447) Avail: NTIS HC A04/MF A01; DFVLR, Cologne, West Germany DM 37

A software concept for electronic displays suitable for a variety of applications in aviation was developed. The hardware of the display system is outlined. The programs for the symbol generator, microprocessor-bipolar, and fixed blanking windows are described. The software was implemented for the proven display technology flown in the Airbus A-310 aircraft. In the light of future developments in display technology, the software provides more features than can be utilized with the hardware currently employed. Electronic displays for a helicopter were taken to demonstrate the software details. ESA

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A88-10358*# Johns Hopkins Univ., Laurel, Md.
EVOLUTION AND APPLICATION OF CFD TECHNIQUES FOR SCRAMJET ENGINE ANALYSIS
M. E. WHITE (Johns Hopkins University, Laurel, MD), J. P. DRUMMOND, and A. KUMAR (NASA, Langley Research Center, Hampton, VA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 423-439. Previously cited in issue 07, p. 894, Accession no. A86-19970. refs

A88-10362#
ANALYTICAL STUDY OF SWIRLER EFFECTS IN ANNULAR PROPULSIVE NOZZLES
JOE D. HOFFMAN, H. DOYLE THOMPSON, and DAVID L. MARCUM (Purdue University, West Lafayette, IN) Journal of Propulsion and Power (ISSN 0748-4658), vol. 3, Sept.-Oct. 1987, p. 465, 466. USAF-sponsored research. Previously cited in issue 07, p. 848, Accession no. A86-19965. refs

A88-10371#
MULTIMODES TO MACH 5
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 25, Sept. 1987, p. 50-53.

Various designs for a variable cycle propulsion system for an SST are analyzed. The objectives of the multimode engine are to combine the performance capabilities of the turbofan, turbojet, ramjet, and scramjet into one design. The advantages and limitations of a turbojet, turboamjet, air turboamjet, variable cycle turbofan ramjet, turboscramjet, and turbine bypass engine are examined and compared. It is noted that the turbine bypass engine is the most effective design proposed. I.F.

A88-10987#
ALTITUDE TESTS OF THE XF3-30 TURBOFAN
MASAYUKI KITAMURA (Japan Defense Agency, Technical Research and Development Institute, Tokyo), MORIMASA UCHIDA (Air Self-Defense Force, Tokyo, Japan), and SATOSHI YASHIMA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p.
(ASME PAPER 87-GT-25)

The XF3-30 turbofan has been successfully developed as the propulsion system for the Japan Air Self Defence Force's XT-4 military intermediate trainer. Altitude tests were conducted four times in ATF and four times on FTB in the engine development program. Utilizing the results of each test, the engine has been improved in sufficient time to meet the aircraft development program schedule, and successful flight tests of XT-4 powered by XF3-30 have been made. Author

A88-10988#
DEVELOPMENT OF THE XF3-30 TURBOFAN ENGINE
HIDEJIRO YAMADA, HIROSHI HAMATANI (Japan Defense Agency, Technical Research and Development Institute, Tokyo), and KAZUHIKO ISHIZAWA (Ishikawajima-Harima Heavy Industries Co., Ltd., Aero-Engine Div, Tokyo, Japan) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p.
(ASME PAPER 87-GT-26)

The XF3-30 is the low-bypass-ratio turbofan engine which has been developed to power the XT-4 intermediate trainer for the Japan Air Self Defence Force. All of the qualification tests including endurance tests, low cycle fatigue test, altitude test, foreign object ingestion test, and environmental icing test were successfully completed by March 1986. A flight test of the XT-4 trainer aircraft

powered by two of the XF3-30 engines has proceeded without any engine-related problems. Author

A88-10993#
INVESTIGATION OF INTEGRATED SELECTION OF OPTIMUM ENGINE CYCLE PARAMETERS
JIN ZHANG, DAGUANG CHEN, XINGJIAN ZHU, and ZHILI ZHU (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. Translation. Previously cited in issue 20, p. 2852, Accession no. A84-41783. refs
(ASME PAPER 87-GT-39)

A method for integrating the selection of optimal aircraft engine cycle parameters is proposed from the viewpoint of system engineering, and a control scheme is proposed which takes into account matching and interaction between the engine and the aircraft. A rapid method for predicting turbojet or turbofan engine off-design performance is adopted and an empirical formula for estimating the engine weight is developed. An augmented engine scheme that meets modification requirements is presented as an example. The results show that the optimum cycle parameters and the control scheme are quite different if the mission, modification requirements, or technical constraints are varied. Author

A88-10996#
FRICTION DAMPING OF RANDOM VIBRATION IN GAS TURBINE ENGINE AIRFOILS
ALOK SINHA (Pennsylvania State University, University Park) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(Contract NSF MSM-85-04579)
(ASME PAPER 87-GT-44)

The optimal value of slip load is calculated for a frictionally damped turbine blade subjected to random excitation. The nature of excitation is assumed to be Gaussian white noise and the statistics of response are obtained using equivalent linearization approach. The results from this technique are compared with those from numerical simulations. Author

A88-10998*# Princeton Univ., N. J.
LOCALIZATION OF NATURAL MODES OF VIBRATION IN BLADED DISKS
O. O. BENDIKSEN (Princeton University, NJ) and N. A. VALERO ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. refs
(Contract NAG3-308)
(ASME PAPER 87-GT-46)

A study is presented of the mode localization phenomenon in imperfect blade-disk and blade-shroud-disk assemblies. The results indicate that unshrouded blades mounted on stiff disks are especially susceptible, and even small blade imperfections within manufacturing tolerances are likely to trigger mode localization. Increasing the interblade coupling by adding shrouds or reducing the disk stiffness greatly reduces the localization susceptiblity, although certain modes may still become localized if the shrouds are free to slip. Author

A88-10999#
COMPRESSOR TURBINE VANE RING (PT6 ENGINE) REPAIR DEVELOPMENT
N. SOURIAL (Pratt and Whitney Canada, Longueuil) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p.
(ASME PAPER 87-GT-47)

A process for repairing the compressor turbine vane ring in the PT6 engine is described. The compressor turbine vane ring consists of 14 air-cooled vanes integrally cast from Co alloys and protected with a thin layer of diffused NiAl coating, and it is located directly at the exit of an annular combustion chamber. The repair procedure involves: subjecting the vane ring to heat treatment in a vacuum furnace; fluorescent penetrant inspection; removal of the burnt section; welding using the tungsten insert gas method; hand blending; brazing compound application; and final inspection. It is noted that this repair technique has reduced the scrappage rate for the vane ring and an average of 100 units are repaired/month. I.F.

A88-11027#
ELECTRONIC TREND MONITORING AND EXCEEDANCE RECORDING SYSTEMS - A MEANS TO IMPROVED TURBINE ENGINE RELIABILITY
MICHAEL G. MOORE (Semco Instruments, Inc., North Hollywood, CA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p.
(ASME PAPER 87-GT-87)

The paper discusses engine-mountable compact microprocessor-based rcording systems that can supply data relevant to the maintenance planning of a turbine engine and, thus, improve its reliability. Consideration is given to the significant data to be recorded, the requirements of an airborne/aircraft recorder, and the information/conclusions available after the analysis of data. The recorded data provide records of an engine/aircraft abuse and maintain cycle counts based upon complex formulas; data are provided in a format that is useful in predicting maintenance requirements. I.S.

A88-11028#
CORRELATIONS OF FUEL PERFORMANCE IN A FULL-SCALE COMMERCIAL COMBUSTOR AND TWO MODEL COMBUSTORS
T. T. BOWDEN, D. M. CARRIER, and L. W. COURTENAY (Shell Research, Ltd., Thornton Research Centre, Chester, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. Research supported by the Ministry of Defence. refs
(ASME PAPER 87-GT-89)

Results from a statistically-designed correlation exercise have demonstrated excellent agreement between the performance of two combustor models and a full-scale Tyne engine combustor, validating the model combustor approach to response and performance prediction. The linear correlations found indicate that only a minimum number of measurements are necessary to confirm the relationship between the model and the full-scale combustor. Results show that a common mechanism of soot formation occurs within all three combustors. R.R.

A88-11029#
EXPERIMENTAL METHOD FOR THE COMBUSTION EFFICIENCY CALCULATION IN A REHEAT DUCT
A. CADIOU (ONERA, Chatillon-sous-Bagneux, France) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. SNECMA-sponsored research. refs
(ASME PAPER 87-GT-90; ONERA, TP NO. 1987-54)

An efficient method for the experimental measurement of the combustion efficiency in a reheat duct is developed, with application to the comparison of different reheat systems. The present downstream to upstream method involves static pressure measurements along the duct, and gas sampling in its outlet cross section. Results are given for a three annular V-gutters flame holder. Optimization is achieved with the present method by trading off betweeen the length of the duct and the pressure drop induced by the flame holder. Experimental correlations concerning the effect of geometrical parameters are performed in order to optimize the size of the combustion reheat system. R.R.

A88-11039#
CURRENT GAS TURBINE COMBUSTION AND FUELS RESEARCH AND DEVELOPMENT
J. E. PETERS (Illinois, University, Urbana) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 17 p. refs
(ASME PAPER 87-GT-107)

Current research and development work on gas turbine combustion and fuels is surveyed on the basis of publications in open literature and of gas-turbine manufacturers' reports. Consideration is given to both aircraft and industrial applications regarding the alternative fuels (in particular, the 'heavier' alternative fuels for aircraft applications), and computer modeling. Two examples of research and development for specific design considerations are illustrated with a discussion of recent efforts on staged combustion for NOx control and on fuel injection. I.S.

A88-11048#
TIME-AVERAGED HEAT-FLUX DISTRIBUTIONS AND COMPARISON WITH PREDICTIO FOR THE TELEDYNE 702 HP TURBINE STAGE
M. G. DUNN (Calspan Corp., Buffalo, NY) and R. E. CHUPP (Teledyne, Inc., Toledo, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. Research supported by Teledyne Independent Research and Development Funds. refs
(ASME PAPER 87-GT-120)

Time-averaged heat-flux distributions for the vane and blade of the CAE 702 HP full-stage rotating turbine are presented, with a shock tube used as a short-duration heat source to which the turbine is subjected, and thin-film gages used to obtain heat-flux measurements. The vane data are shown to be bounded by the turbulent flat plate and the fully turbulent STAN 5 prediction models, and the blade data are found to be well predicted by the k-epsilon model on both the pressure and the suction surfaces. The STAN 5 fully turbulent calculation for the blade is shown to fall above the data, and the STAN 5 fully laminar calculation to fall substantially below the data. R.R.

A88-11066#
THE PERFORMANCE ESTIMATION OF TRANSONIC TURBINE AT DESIGN AND OFF-DESIGN CONDITIONS
MANCHU GE (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-148)

A performance estimation method for the determination of the gasdynamic parameters of turbines at design and off-design conditions is presented. The method involves the simultaneous solution of equations including the S2 stream surface equation, the loss equations, and the deviation angle correction. The approach is shown to avoid the false choking condition and to achieve rapid convergence. The reduced flow rate, efficiency, and expansion ratio are found to agree well with experimental results, with a difference of within 1 percent between computational and experimental data near the design condition. R.R.

A88-11070#
ON PREDICTING THE RESONANT RESPONSE OF BLADED DISK ASSEMBLIES
J. H. GRIFFIN (Carnegie-Mellon University, Pittsburgh, PA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(Contract F33615-84-C-2454)
(ASME PAPER 87-GT-158)

The vibratory response of blades in gas turbine engines varies because of mistuning. An approach is developed for calculating the statistical distribution of peak resonant stresses in engine blading. It is used to predict the vibratory response of an unshrouded fan stage. The results of the calculation compare favorably with test data for the lower frequency modes. The procedure can be used to predict fleet durability and offers a practical engineering approach for dealing with stage mistuning. Author

A88-11076#
VERIFICATION OF COMPRESSOR DATA ACCURACY BY UNCERTAINTY ANALYSIS AND TESTING METHODS
N. D. POTTI and D. C. RABE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p.
(ASME PAPER 87-GT-165)

A transonic compressor designed and instrumented by the General Electric Company was recently evaluated during several test programs in the Compressor Research Facility at Wright-Patterson Air Force Base. An analytical uncertainty analysis was performed for the individual measurements, as well as the calculated performance parameters. During the tests, the experimental values of precision uncertainty were compared to the analytical predictions. The spatial variation of the individual discharge measurements was evaluated for its effect on the uncertainty of the measured parameters and calculated performance. Through the comparison of the analytical and measured uncertainty and the evaluation of spatial variation, a final uncertainty of the measured performance is presented, and the overall quality of the test results is assessed. Through these data reviews, a more accurate understanding of the performance of the test compressor is obtained. Author

A88-11078#
INTRODUCTION AND APPLICATION OF THE GENERAL ELECTRIC TURBINE ENGINE MONITORING SOFTWARE WITHIN KLM ROYAL DUTCH AIRLINES
HANS LUCAS (KLM Royal Dutch Airlines, Schiphol Airport, Netherlands) and JOHN E. PAAS (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-167)

The development, design, and application of the Ground-based Engine Monitoring (GEM) system are described. The monitoring system combines multiple engine performance and mechanical analysis functions into a single ground-based computer system. The multiple functions and capabilities of the GEM, which include engine performance, vibration signals, and engine control parameters analyses, performance simulation, and automatic trend shift recognition and alter functions, are examined. The integration of the GEM into the KLM operations, and the benefits provided by the system are discussed. I.F.

A88-11079*# Pratt and Whitney Aircraft, West Palm Beach, Fla.
CONCEPTUAL DESIGN OF AN OPTIC BASED ENGINE CONTROL SYSTEM
W. J. DAVIES (Pratt and Whitney, Engineering Div., West Palm Beach, FL), R. J. BAUMBICK (NASA, Lewis Reserach Center, Cleveland, OH), and R. W. VIZZINI (U.S. Navy, Naval Air Propulsion Test Center, Trenton, NJ) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p.
(ASME PAPER 87-GT-168)

Use of optics in the aircraft engine control systems would provide immunity to electromagnetic effects (such as lightning, radar, and nuclear pulses) for flight and propulsion control systems located throughout the aircraft and in need of communication and would result in weight reduction. This paper discusses a conceptual design of an optic engine control system that is being developed by the Fiber Optic Control System Integration (FOCSI) program. The features inherent in each of the optic-based components of the optic system, which includes the on-engine full authority digital electonic control, optic sensors, optic-based actuators, and an optic data bus for communication with the aircraft flight control system are described in detail. The diagrams of the FOCSI control system and its components are included. I.S.

A88-11085#
PREDICTION OF GAS TURBINE COMBUSTOR-LINER TEMPERATURE
YOUSEF S. H. NAJJAR (King Abdulaziz University, Jeddah, Saudi Arabia) and RIAD M. DROUBI ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-177)

Broadening of fuel specifications decreases the hydrogen content and increases the aromatics and final boiling point. The cumulative effect will be an increase in soot formation hence flame radiation which affects flame tube durability. In this work an analytical study is made where empirical formulae are developed for luminosity, radiation and convection at idle and full load conditions. These equations predict combustor liner temperature with high degree of agreement with previous experimental work. Author

A88-11090#
A NEW METHOD (FTDCDF) FOR THE BLADE DESIGN OF AXIAL/MIXED-FLOW COMPRESSIONS AND ITS APPLICATIONS
CHUAN-GANG GU (Xian Jiaotong University, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-183)

A new design method with unequal work along the height of the blade in axial/mixed-flow compressors, called The Flow-Type Design of Controlled Diffusion Factors (FTDCDF), is described. The idea of the method is to control the distribution of the diffusion factors along the height of the blade in the vaneless space in order to design a blade with good aerodynamic properties. The theoretical basis of FTDCDF and its computational method are studied in detail. Comparison between the results of this method and those of others shows that the FTDCDF program has good accuracy and convergence. Author

A88-11094#
THE AEROMECHANICAL RESPONSE OF AN ADVANCED TRANSONIC COMPRESSOR TO INLET DISTORTION
J. T. DATKO, JR. and J. A. O'HARA (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. refs
(ASME PAPER 87-GT-189)

An advanced transonic compressor was tested in the Compressor Research Facility at the Aero Propulsion Laboratory. The compressor was operated with seven different total-pressure distortion screens located at the inlet, along with baseline testing of two 'clean' inlet configurations. Of particular interest was the forced vibratory reponse of the first-stage integrally bladed disk (blisk) to the various distortions. This paper presents a summary of the blisk vibratory responses to each of the distortion screens. Effects of instrumentation on the dynamic response of the blisk are illustrated. Author

A88-11107#
THE UNITED KINGDOM ENGINE TECHNOLOGY DEMONSTRATOR PROGRAMME
W. J. CHRISPIN (Ministry of Defence /Procurement Executive/, London, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p.
(ASME PAPER 87-GT-203)

The engine technology demonstrator programs in the UK are discussed. These programs are needed to ensure that engine technologies are available prior to full-scale engineering development and to reduce development risks and costs. The programs generate fundamental design concepts and evaluate them at rig and component levels; the integrated approach used in the programs is described, and an example demonstrating its applicability is presented. The relationship between government and industry in the operation of the demonstrations, in particular funding and program management, is considered. The demonstrator program structure from conception to transition to full-scale development is examined and a model is provided. I.F.

A88-11110#
VELOCITY SCALED AEROELASTIC TESTING OF ADVANCED TURBOPROPS
EDWARD F. CRAWLEY and ERIC H. DUCHARME (MIT, Cambridge, MA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. Research supported by General Electric Co. refs
(ASME PAPER 87-GT-209)

An innovative experimental procedure for the subvelocity scale testing of anisotropic aeroelastic models is developed and applied to the Advanced Turboprop. The scaling laws for an anisotropic, rotating model are developed. These scaling laws indicate that by proper choice of model geometry, stiffness, and density, all of the important aeroelastic similarity parameters can be satisfied in a full-velocity scaled test. In a subvelocity scaled test, all the similarity parameters except for the Mach number can be matched. The development of the model building technology to construct reduced stiffness anisotropic models for subvelocity scaled testing is then reviewed. In order to experimentally verify the sub-velocity scaled procedure, a propeller model was constructed based on the G.E. UDF MPS model, and the aeroelastic and performance data are favorably compared. Finally, as an illustration of the versatility of the sub-velocity scaled approach, the model is used to demonstrate the sensitivity of ATP blade flutter to mass distribution. Author

A88-11111#
DIGITAL CONTROLS FOR GAS TURBINE ENGINES
K. ROBINSON (Dowty and Smiths Industries Controls, Ltd., Cheltenham, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 13 p. refs
(ASME PAPER 87-GT-211)

The functional requirements of gas turbine engine control systems and the application of electronic control systems to the fulfilling of these requirements are considered. British Civil Certification and commercial requirements for digital engine control systems (DECs) are discussed, in addition to issues involved in the trade-off between system integrity and reliability. Several Full Authority Digital Engine Controls (FADEC) programs are described, including DECs for turboshafts, turboprops, a VTOL aircraft, a large civil fan-engine, remote piloted vehicles, and augmented engines. A FADEC configuration consisting of two lanes in one and using only three microprocessors is also considered. R.R.

A88-11113#
THE TURBOMACHINE BLADING DESIGN ACHIEVED BY SOLVING THE INVERSE FIELD PROBLEM
T. S. LUU and B. VINEY (CNRS, Laboratoire d'Informatique pour la Mecanique et les Sciences de l'Ingenieur, Orsay, France) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-215)

The paper describes a design procedure for the determination of the geometry of the blading of the turbomachine with prescribed thickness and bound vorticity distribution. An optimized two-dimensional cascade design example is shown. The quasi-three-dimensional 'S2'-'S1' stream function formulation is developed. The design of guide vanes downstream of a lateral inlet casing is described. A new approach by introducing a potential like function to treat the three-dimensional rotational flow is also formulated. Author

A88-11122#
AGT101 - CERAMIC GAS TURBINE DEVELOPMENT
G. L. BOYD, M. L. EASLEY, and D. M. KREINER (Garrett Turbine Engine Co., Phoenix, AZ) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 17 p.
(ASME PAPER 87-GT-228)

The critical ceramic component development and the engine evaluation of the ceramic hot section in the AGT101 are described. Ceramic structure test evaluation at 2500 F, ceramic combustor operation using various fuels, and ceramic static seal leakage reduction are reported. Fabrication development of the turbine rotor is emphasized. A 100-hr engine test of the ceramic structures to 2100 F, and an 85-hr engine test of the all-ceramic hot section to 220 F, have been accomplished, and full speed operation to 100,000 rpm and a ceramic rotor tip speed of 3200 ft/sec have been demonstrated. R.R.

A88-11123#
A TRADE-OFF STUDY OF ROTOR TIP CLEARANCE FLOW IN A TURBINE/EXHAUST DIFFUSER SYSTEM
SAEED FAROKHI (Kansas, University, Lawrence) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-229)

In a modern gas turbine power plant, the axial exhaust diffuser accounts for up to 10 percent of the generator power. An unshrouded rotor, due to its highly energetic tip clearance flow, improves the pressure recovery characteristic of the exhaust diffuser, while the power production within the blading suffers a loss as a result of the tip leakage flow. In this paper, these conflicting trends are thermodynamically investigated and nondimensional expressions are derived which facilitate the task of a gas turbine system designer. Conservatively, 1 percent thermal efficiency gain results from elimination of the last rotor tip clearance flow. Author

A88-11127#
BOUNDARY LAYER PROFILE INVESTIGATIONS DOWNSTREAM OF AN AERO-ENGINE INTAKE ANTI-ICING AIR EXHAUST SLOT
S. J. DOWNS (Rolls-Royce, PLC, Derby, England) and E. H. JAMES (Loughborough University of Technology, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p.
(ASME PAPER 87-GT-237)

The boundary-layer profile downstream of the antiicing air (AIA) exhaust slot of a two-dimensional aero-engine inlet section was investigated by means of a pitot rake. Results are presented for a range of inlet air flows with and without exhaust AIA introduced. The boundary layer was found to be turbulent, owing to the presence upstream in the wind tunnel of a fixed water spray grid. Injection of AIA produced a sublayer downstream of the AIA exhaust plane. Three methods of deriving boundary-layer thickness from the experimental data were used, and the experimental measurements confirmed theoretical predictions. Author

A88-11128#
GAS TURBINE EXHAUST SYSTEMS - DESIGN CONSIDERATIONS
ROY A. MORRIS (Cullum Detuners, Ltd., Heanor, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p.
(ASME PAPER 87-GT-238)

This paper discusses the specifications which the prospective user of a gas turbine should give to the designer of the power-turbine exhaust system. Basic factors include the initial acoustic performance of the particular installation (considering, in particular, the inadequacy of the dBA weighting criteria for use in locations near residential areas) and the importance of multiple-set installations. Other important elements in the overall acoustic performance of an the installation are the plant design, the exhaust gas path, and the types of materials and finishes. The components common to typical gas turbine exhaust silencer are examined in detail. An arrangement diagram is included. I.S.

A88-11137*# McDonnell Aircraft Co., St. Louis, Mo.
HIDEC ADAPTIVE ENGINE CONTROL SYSTEM FLIGHT EVALUATION RESULTS
W. A. YONKE, R. J. LANDY (McDonnell Aircraft Co., Saint Louis, MO), and J. F. STEWART (NASA, Flight Research Center, Edwards AFB, CA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-257)

An integrated flight propulsion control mode, the Adaptive Engine Control System (ADECS), has been developed and flight tested on an F-15 aircraft as part of the NASA Highly Integrated Digital Electronic Control program. The ADECS system realizes additional engine thrust by increasing the engine pressure ratio (EPR) at intermediate and afterburning power, with the amount of EPR uptrim modulated using a predictor scheme for angle-of-attack and sideslip angle. Substantial improvement in aircraft and engine performance was demonstrated, with a 16 percent rate of climb increase, a 14 percent reduction in time to climb, and a 15 percent reduction in time to accelerate. Significant EPR uptrim capability was found with angles-of-attack up to 20 degrees. R.R.

A88-11139#
CYCLIC SPINNING TESTING OF AERO-ENGINE DISCS
H. AOANO, T. CHIKATA, R. SATOH, T. WAKATSUKI, and M. HIKITA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-259)

Aero-engine disks must demonstrate sufficient low-cycle-fatigue lives. Here, results from several cyclic spinning tests are reported. During the testing, some disks were burst, and some disks were cracked. Through the experience of the testing, a technique for detecting crack initiation in the disks during spinning tests is developed. Using this technique, it is possible to stop driving before the disks would burst. Procedures and data are presented in detail. Author

A88-11196
WIND TUNNEL TESTING OF SMALL SCALE PRESSURE TAPPED MODEL PROPELLERS
D. W. HURST, D. T. OWEN (Southampton, University, England), and P. N. METHVEN (Dowty Rotol, Ltd., Gloucester, England) IN: Aerodynamics at low Reynolds numbers Re greater than 10 to the 4th and less than 10 to the 6th; Proceedings of the International Conference, London, England, Oct. 15-18, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 21.1-21.22. refs

Wind tunnel tests conducted to study the scale effects resulting from the use of small-scale pressure-tapped models instead of full-scale propellers are described. The tested propeller blade had a diameter of 0.705 m and a chord of 0.049 m at 70 percent radius. The blade had 24 chordwise tappings positioned at seven spanwise stations, producing a total of 168 measuring points. Results from proving trials on this propeller model are included which show the effects of changes in rotational speed, blade angle, free-stream velocity, and number of blades on the pressure distribution. Scale effect results are reproduced for both the static running condition and nonstatic conditions. The results show that, over the measured operating range, models of this size can be safely used to represent conventional full-scale propellers. C.D.

A88-11923#
THE DEVELOPMENT OF 270 VDC SOLID STATE POWER CONTROLLERS
R. Y. KINOSHITA, P. E. MCCOLLUM, and M. E. COLAN (Rockwell International Corp., Anaheim, CA) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 905-910.

The electrical, mechanical and thermal designs of microprocessor-based 270 Vdc Solid State Power Controllers (SSPCs), developed using NADC specifications, are discussed. The SSPCs combine the capabilities to perform all the needed functions of load switching, overload protection, remote control, and Built-In-Test. The Solid-State Electric Logic interface linking the system controller and the SSPC controller is described, in addition to the current monitor. The controller design is based on an eight-bit factory mask-programmable ROM CMOS microprocessor, and the main power switch is designed using power MOSFETs. Power is provided by an efficient, low power, multiple output power supply. R.R.

A88-11976#
AN IMPROVED STIRLING ENGINE FOR MODEL AIRCRAFT PROPULSION
ROB MCCONAGHY (New Machine Co., Kirkland, WA) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 4 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1831-1834. refs

The design of an improved Stirling engine for model aircraft propulsion is described. The engine is based on a previously designed single cylinder, Beta-type engine which ran well but fell far short of the goal for power to weight ratio (300-400 W/kg). The paper describes design changes and test results for an improved version of this engine. Lightweight, tubular heat exchangers replace the annular gap type previously used. Better dynamic balance has also been achieved. Author

A88-12836
PLUME INFRARED SIGNATURE MEASUREMENTS AND COMPARISON WITH A THEORETICAL MODEL
SANTO COGLIANDRO and PAOLA CASTELLI (Rinaldo Piaggio - Industrie Aeronautiche e Meccaniche S.p.A., Finale Ligure, Italy) IN: Infrared technology XII; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 73-79.

The identification of the most important parameters in the plume IR emissions of rotorcraft turboshaft engines is presently undertaken in the 1-14.5 micron band by a spectroradiometer, whose field test measurement results are then compared with those of a computer model. Spatial results, which are available in 128 x 128-element images, are important to the understanding of such phenomena as turbulence and nonaxisymmetric emission. Atmospheric transmittance and background emission are measured in order to yield the most realistic IR signatures possible. The results are being applied in a rotorcraft IR signature-suppression program. O.C.

A88-13076#
CURRENT DESIGN STATUS AND DESIGN TREND OF FUEL INJECTORS FOR JET ENGINES
YUKINORI SATO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 393, 1986, p. 519-530. In Japanese. refs

Technological trends in fuel-injector design for jet engines are reviewed along with the efficiency parameters and requirements for jet-engine combustors. The functional characteristics of air blast, pressure blast, rotary, and evaporative fuel injectors are compared. The designs of various air-blast injectors are considered. S.H.

A88-13095#
THE SCRAMJET - TOWARD MACH 4-25 FLIGHT
NOBUO CHINZEI and GORO MASUYA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 400, 1987, p. 241-252. In Japanese. refs

Technological problems in the development of the scramjet are characterized, and scramjet R&D in the United States and Japan is reviewed. Work from 1960 to 1975 is summarized, including the free-jet engine, the variable geometry engine, the component integration model, and the thermal compression engine. Also considered is work after 1975, including the airframe integrated engine and the dual combustor engine. S.H.

N88-10032 Arizona State Univ., Tempe.
MODELING AND MEASUREMENT OF HEAT TRANSFER ON TURBINE BLADE TIPS Ph.D. Thesis
HEE-KOO MOON 1987 229 p
Avail: Univ. Microfilms Order No. DA8711465

Local mass transfer measurements are made for flow through a narrow slot-type channel where one of the boundary walls contains a transverse rectangular cavity and the other is in motion. The study models heat transfer on the grooved tips of axial turbine blades. A naphthalene sublimation technique together with a microcomputer-controlled measurement system provides detailed local mass transfer information. Overall mass transfer is not measurable affected by the moving boundary for cavity depth-to-width ratios of 0.10, 0.25, 0.50, 1.00, and 1.50. As cavity depth increases, overall mass transfer stays essentially the same until the immediate depth-to-width ratio of 0.5 is reached, then increases. The direction of the moving wall relative to the mean flow direction does not effect the overall mass transfer but does change local distributions, especially on the cavity floor and side walls. Stanton number averaged over the entire tip area decreases exponentially with gap Reynolds number over the test range of .38 to 3.6 x 10 to the 4th power, but overall mass transfer increases. Gap clearance is inversely related to overall mass transfer and influences significantly the local mass transfer distribution in the gap regions. Dissert. Abstr.

N88-10033# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
FLAME DRIVING OF LONGITUDINAL INSTABILITIES IN LIQUID FUELED DUMP COMBUSTORS Final Report, 1 Jul. 1984 - 30 Jun. 1987
BEN T. ZINN, UDAY G. HEGDE, DIERK REUTER, and B. R. DANIEL 1 Jul. 1987 114 p
(Contract N00014-84-K-0470)
(AD-A183536) Avail: NTIS HC A06/MF A01 CSCL 21B

This report describes the results of experimental and theoretical investigations of the mechanisms by which the core flow combustion process in coaxial, single inlet, dump type ramjet engines drives longitudinal combustion instabilities. To this end, the behavior of V-shaped flames, similar to those often occurring in ramjet combustors, stabilized in longitudinal acoustic fields has been studied. The presence of burning vortical structures is observed in the flame region. These structures appear at frequencies close to the first natural acoustic frequency of the combustor and are believed to be connected with a shear layer type of instability of the flame. Experiments conducted show that the unsteady combustion in these structures is capable of driving the acoustics at the fundamental acoustic mode frequency. With increase in fuel air ratio, a spontaneous instability involving the fundamental mode is observed and explained in terms of increased driving associated with the higher, unsteady heat release rates. The results of experiments conducted with external acoustic excitation of the flame at different frequencies are also reported and confirm the idea that the vortical structures arise due to a fluid mechanical instability of the flame. It is shown that the interactions between the vortical structures and the system's acoustic field affect the heat release rates from the flame and provide a mechanism for the driving of longitudinal mode instabilities. GRA

N88-10035# Technische Hochschule, Aachen (West Germany). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.
INVESTIGATION OF THE EXCITATION OF TURBINE BLADE VIBRATION IN AXIAL COMPRESSORS IN ROTATING STALL Final Report [UNTERSUCHUNG DER SCHWINGUNGSERREGUNG VO LAUFSCHAUFELN IN AXIALVERDICHTERN BEI ROTATING STALL]
W. MOLL Oct. 1986 64 p In GERMAN
(Contract DFG-KO-786/2-3-DER)
(ETN-87-90377) Avail: NTIS HC A04/MF A01

Measurements were performed on the seven-stage axial compressor of a gas turbine to study the characteristics of the rotating separation zones in the first stages and their effects on the production of vibrations. A contactless optoelectronic measuring system for rotating compressor turbines was developed. The unsteady flow quantities in the seven-stage compressor in rotating stall were determined using the split-film-probe measuring technique. A calculation model for the prediction of the compressor behavior in the first stage of the axial compressor was developed on the basis of a nonlinear theory. ESA

N88-10037# Technische Univ., Munich (West Germany). Fakultaet fuer Maschinewesen.
EXPERIMENTAL DETERMINATION OF THE OSCILLATORY FORCES ON TWO TURBINE BLADE PROFILES Ph.D. Thesis [EXPERIMENTELLE BESTIMMUNG DER SCHWINGUNGSERREGERKRAEFTE ZWEIER TURBINENSCHAUFELPROFILE]
MICHAEL HUBENSTEINER 1986 151 p In GERMAN Sponsored by Deutschen Forschungsgemeinschaft, West Germany
(ETN-87-90417) Avail: NTIS HC A08/MF A01

The behavior of two 50%-reaction blades of different profile shape in the case of cascade interference under steady and unsteady flow was investigated in a cascade wind tunnel. The pressure distribution along the blade profiles was measured as a function of the relative position of the blades. The friction wake for both profiles was determined for different cascade distances. The unsteady pressure distribution on the blade profiles was measured in an air test turbine, and the oscillatory forces were deduced. The amplitude of the oscillation depends on the axial distance between the cascades, the velocity triangles in the stage, and the relative position of the blades in the neighboring oscillating cascade. Harmonics of the oscillatory forces were observed. The results show that production defects in the cascades can lead to significant unsteady forces on the blades. ESA

N88-10789# Rolls-Royce Ltd., Derby (England).
THE WIDE CHORD FAN BLADE: A ROLLS ROYCE FIRST
D. J. NICHOLAS 1 Jun. 1987 31 p Presented at the 8th ISABE Conference, Cincinnati, Ohio, 15-19 Jun. 1987
(PNR90416; ETN-87-91005) Avail: NTIS HC A03/MF A01

The performance benefits of the wide chord fan compared to the conventional, snubbered, high aspect ratio design are described. The main mechanical design aspects of the fabricated blade are outlined. Criteria such as the choice of blade numbers, FOD resistance, cyclic fatigue, and vibration characteristics are examined together with the computer modeling and method of stressing which ensures the correct aerodynamic shape under centrifugal and pressure load conditions. The physical construction of the blade and the method of manufacture are summarized. The RB 211-535 E4 service record is reviewed. ESA

N88-10791*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
BLADE LOSS TRANSIENT DYNAMICS ANALYSIS, VOLUME 1. TASK 2: TETRA 2 THEORETICAL DEVELOPMENT Final Report
VINCENTE C. GALLARDO and GERALD BLACK Nov. 1986 92 p
(Contract NAS3-24381)
(NASA-CR-179632; NAS 1.26:179632) Avail: NTIS HC A05/MF A01 CSCL 21E

The theoretical development of the forced steady state analysis of the structural dynamic response of a turbine engine having nonlinear connecting elements is discussed. Based on modal synthesis, and the principle of harmonic balance, the governing relations are the compatibility of displacements at the nonlinear connecting elements. There are four displacement compatibility equations at each nonlinear connection, which are solved by iteration for the principle harmonic of the excitation frequency. The resulting computer program, TETRA 2, combines the original TETRA transient analysis (with flexible bladed disk) with the steady state capability. A more versatile nonlinear rub or bearing element which contains a hardening (or softening) spring, with or without deadband, is also incorporated. Author

N88-10792*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
BLADE LOSS TRANSIENT DYNAMICS ANALYSIS, VOLUME 2. TASK 2: TETRA 2 USER'S MANUAL Final Report
GERALD BLACK and VINCENTE C. GALLARDO Nov. 1986 204 p
(Contract NAS3-24381)
(NASA-CR-179633; NAS 1.26:179633) Avail: NTIS HC A10/MF A01 CSCL 21E

This is the user's manual for the TETRA 2 Computer Code, a program developed in the NASA-Lewis Blade Loss Program. TETRA 2 calculates a turbine engine's dynamic structural response from applied stimuli. The calculation options are: (1) transient response; and (2) steady state forced response. Based on the method of modal syntheses, the program allows the use of linear, as well as nonlinear connecting elements. Both transient and steady state options can include: flexible Bladed Disk Module, and Nonlinear connecting elements (including deadband, hardening/softening spring). The transient option has the additional capability to calculate response with a squeeze film bearing module. TETRA 2 output is summarized in a plotfile which permits post processing such as FFT or graphical animation with the proper software and computer equipment. Author

N88-10992# Joint Publications Research Service, Arlington, Va.
TURBINES WITH COUNTERROTATING RUNNERS FOR AIRCRAFT POWER PLANTS Abstract Only
B. A. PONOMAREV and YU. V. STOSENKO *In its* USSR Report: Engineering and Equipment p 93 4 May 1987 Transl. into ENGLISH from Izvestiya Vysshikh Uchebnykh Zavedeniy: Aviationnaya Tekhnika (Kazan, USSR), no. 2, Apr. - Jun. 1986 p 50-53 Original language document was announced in IAA as A87-15211
Avail: NTIS HC A07/MF A01

A classification of turbines with counter rotating rotors is presented, and their classifications in aircraft power plants of various types are examined. The principal gasdynamic characteristics of the traditional (fixed stator) and nontraditional (birotational) turbine designs are discussed. For birotational turbines, characteristic kinematic relationships are obtained, and an expression is proposed for determining the gasdynamic loading parameter. E.R.

N88-10993# Joint Publications Research Service, Arlington, Va.
DIAGNOSIS OF FLOW CHANNEL IN AIRCRAFT GAS-TURBINE ENGINES ON BASIS OF VIBRATION SPECTRUM CHARACTERISTICS Abstract Only
A. G. MIRONOV and S. M. DOROSHKO *In its* USSR Report: Engineering and Equipment p 93 4 May 1987 Transl. into ENGLISH from Izvestiya Vysshikh Uchebsnykh Zavedeniy: Aviatsionnaya Tekhnika (Kazan, USSR), no. 2, Apr. - Jun. 1986 p 45-49 Original language document was announced in IAA as A87-15210
Avail: NTIS HC A07/MF A01

An improved vibration spectrum model is presented which allows for the presence of combination components. Methods are then examined for evaluating the aerodynamic inhomogeneity of a rotor of a dual shaft gas turbine engine from the vibration parameters based on the combination components. The accuracy of the results is confirmed experimentally. E.R.

N88-11152*# Garrett Turbine Engine Co., Phoenix, Ariz.
COMBUSTOR-DIFFUSER INTERACTION PROGRAM
R. SRINIVASAN and C. WHITE *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 121-125 Oct. 1985
(Contract F33615-84-C-2427)
Avail: NTIS HC A19/MF A01 CSCL 21E

A collection of empirical and analytical design methodology on combustor-diffuser systems was completed. A fully elliptic code was selected for analyzing the combustor-diffuser interaction. Analytical model predictions were obtained for all flow conditions at which Phase 2 tests will be conducted. These results will be compared with laser doppler velocimeter data. Furthermore, a generalized nonorthogonal grid system is being developed to accurately simulate complex wall shapes. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

A88-10095#
SYNTHESES OF REDUCED-ORDER CONTROLLERS FOR ACTIVE FLUTTER SUPPRESSION
ATSUSHI FUJIMORI and HIROBUMI OHTA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 402, 1987, p. 353-362. In Japanese, with abstract in English. refs

Reduced-order controllers for active flutter suppression of a two-dimensional airfoil are studied using two design approaches. One is based on the generalized Hessenberg representation (GHR) in the time domain, and the other, called the Nyquist frequency approximation (NFA), is a method in the frequency domain. In the NFA method, the reduced-order controllers are designed so that the stability margin of the Nyquist plot may be increased over a specific frequency range. To illustrate and to make a comparison between the two methods, numerical simulations are carried out using a thirteenth-order controlled plant. It is to be noted that the GHR method can yield quasi-optimal controllers in the sense of minimizing quadratic performance indices. The designed controllers, however, do not have enough stability margin, and the order reduction resulting from full state controllers may not be satisfactory. On the other hand, reduced-order controllers in the NFA method can be designed with increased stability margin at the expense of the performance index. For all simulation cases, the NFA method yields second-order controllers with a better stability margin than those by the GHR method. Thus, the NFA method provides an effective method for synthesizing robust reduced-order controllers. Author

A88-10159* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
FLYING COMPLEX APPROACH PATHS USING THE MICROWAVE LANDING SYSTEM
CHARLES E. KNOX (NASA, Langley Research Center, Hampton, VA) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 65-82. refs
(SAE PAPER 861771)

A piloted simulation study was conducted to examine the requirements for using electromechanical flight instrumentation to provide guidance for manually controlled flight along complex, curved approach paths within the microwave landing system signal coverage. The data from these tests indicated that flight director guidance is required for the manually controlled flight of a jet transport airplane on complex, curved approach paths. Each of the three guidance algorithms tested could be used to fly the paths. However, pilot comments indicated that the use of guidance based on capturing the next straight path segment may not be acceptable since full-scale lateral deflections normally resulted during turns. Pilot comments indicated that all the approach paths tested could be used in normal airline operations. Approach paths with both multiple, sequential turns and short final path segments were demonstrated. Author

A88-10163
IMPROVEMENTS IN AIRCRAFT SAFETY AND OPERATIONAL DEPENDABILITY FROM A PROJECTED FLIGHT PATH GUIDANCE DISPLAY
JOHN DESMOND (Flight Dynamics, Inc., Portland, OR) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 113-124. refs
(SAE PAPER 861732)

The advantages that can be gained in aircraft safety and operating dependability through the use of projected flight path guidance are discussed. During a test program developed to determine the improvement in approach path control and touchdown precision afforded by a projected flight path display, it was found that the availability of this information reduced the touchdown footprint, eliminated the short and long landings, and reduced the number of go-arounds from six to zero. With the inertial flight path, pilots can identify not only the windshear event, but also the effect of the shear and the pilot's recovery action against it. The ability of pilots using the HUD Guidance System to meet the requirements of CAT III operations is evaluated. K.K.

A88-10164
THE ADVANTAGE OF FLIGHTPATH-ORIENTED SITUATION DISPLAYS DURING MICROBURST ENCOUNTERS
J. G. OLIVER (Air Line Pilots Association, Washington, DC) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 125-127.
(SAE PAPER 861733)

It is maintained that the conventional instruments mounted in commercial cockpits today do not adequately provide the information necessary to enable a pilot to recognize the onset of a microburst early enough or to fly an optimum flightpath thereafter. An integrated instrument display that would portray the aircrafts's actual flightpath integrated with an efficient, confusion-free display of airspeed or angle of attack and altitude above terrain is needed. It is concluded that the accident rate will remain the same until a predictory detection device is developed or flight-path oriented instrumentation is made available. K.K.

A88-10167
AIRLINE REQUIREMENTS ON A FLY-BY-WIRE AIRCRAFT - A PILOT'S VIEW
PETER H. HELDT (Deutsche Lufthansa AG, Cologne, Federal Republic of Germany) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 177-179.
(SAE PAPER 861804)

The advantages of a fly-by-wire aircraft include added safety features, improved handling characteristics, reduction of training costs, and more flexibility in flight deck arrangement. The paper discusses the ways in which these features match the operational requirements of airlines. Particular attention is given to the flight deck arrangement, system architecture, the controller, handling, training, control laws and safety, and evaluation. K.K.

A88-12487
A MATHEMATICAL MULTI-POINT MODEL FOR AIRCRAFT MOTION IN MOVING AIR
R. BROCKHAUS (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, May-June 1987, p. 174-184. refs

The nonlinear equations of aircraft motion in moving air are introduced and their interactions illustrated by block diagrams. This mathematical model reflects the fact that wind and aircraft motion are strongly coupled, aircraft forces and moments being generated by the relative motion between the air and the aircraft. The usual one-point model is first considered, using the classical approach of overall quasi-steady derivatives. This is developed to provide a multipoint model, in which the effects of aircraft rotation, wind gradients, wing downwash, and engine flow can be modeled more precisely by a generalized approach. Quasi-steady terms are replaced by the calculation of local velocities and forces. This approach has great potential for improving the accuracy with which aircraft motion is simulated. C.D.

A88-12646
RECENT TILT ROTOR FLIGHT CONTROL LAW INNOVATIONS
DWAYNE F. KIMBALL (Bell Helicopter Textron, Fort Worth, TX) American Helicopter Society, Journal (ISSN 0002-8711), vol. 32, July 1987, p. 33-42. refs

This paper describes three distinct control law functions recently developed in conjunction with full-scale development of the Bell-Boeing V-22 Osprey tilt rotor. Two of these are designed to improve the speed response of the aircraft. The first quickens thrust response to power lever inputs by varying proprotor RPM through a governor feedforward circuit. The second gives the power lever direct control of an aerodynamic brake formed by the aircraft's flaperon control surfaces. The third control law function is a model follower concept for mast torque control which protects against drive system overtorque and reduces thrust axis workload in all flight modes. The paper discusses the handling qualities of the aircraft that prompted the development of these functions, and the improvements resulting from each as determined by analysis and flight simulation. Author

A88-13080#
DESIGN STUDY FOR AN FBW LATERAL CONTROL SYSTEM
YUICHI HONDA, YASUO TAKEUCHI, and HISANAO NAKAYAMA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 600-607. In Japanese. refs

A fly-by-wire (FBW) lateral control system for transport aircraft has been designed, and its safety and reliability have been investigated. System control requirements and examples of control-system failure for the FAR 25 are discussed. Flying quality requirements are discussed along with problems in the design of the FBW control system. S.H.

N88-10038# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
FLUTTER SUPPRESSION AND GUST LOAD ALLEVIATION. PART 1: RESULTS OF PHASE 1 TO 3. PART 2: DESCRIPTION OF THE GARTEUR MODEL
H. HOENLINGER, R. MANSER, and D. MUSSMANN 20 Mar. 1985 64 p
(MBB-LKE292/S/PUB/191; ETN-87-90579) Avail: NTIS HC A04/MF A01

An adaptive flutter suppression system using target functions to adjust gain and phase of the control law was developed. The system was installed in a flutter model and tested successfully. The flutter speed can be increased 38%. A gust load alleviation system was developed and tested on the model. Flutter suppressor and gust load alleviation systems were combined and investigated under gusts. The wing root bending moment of the model can be decreased considerably. The model used for testing active control technology is described. It is a dynamically scaled subsonic model with hydraulically driven control surfaces. Basic geometry and mass data are given. The model instrumentation, model suspension, and wind tunnel test set up is explained. ESA

N88-10039*# Systems Technology, Inc., Hawthorne, Calif.
INVESTIGATION OF INTERACTIONS BETWEEN LIMB-MANIPULATOR DYNAMICS AND EFFECTIVE VEHICLE ROLL CONTROL CHARACTERISTICS Final Report
D. E. JOHNSTON and D. T. MCRUER Washington NASA May 1986 65 p Previously announced as N86-32991
(Contract NAS2-11454)
(NASA-CR-3983; H-1320; NAS 1.26:3983) Avail: NTIS HC A04/MF A01 CSCL 01C

A fixed-base simulation was performed to identify and quantify interactions between the pilot's hand/arm neuromuscular subsystem and such features of typical modern fighter aircraft roll rate command control system mechanization as: (1) force sensing side-stick type manipulator; (2) vehicle effective role time constant; and (3) flight control system effective time delay. The simulation results provide insight to high frequency pilot induced oscillations (PIO) (roll ratchet), low frequency PIO, and roll-to-right control and handling problems previously observed in experimental and production fly-by-wire control systems. The simulation configurations encompass and/or duplicate actual flight situations, reproduce control problems observed in flight, and validate the concept that the high frequency nuisance mode known as roll ratchet derives primarily from the pilot's neuromuscular subsystem. The simulations show that force-sensing side-stick manipulator force/displacement/command gradients, command prefilters, and flight control system time delays need to be carefully adjusted to minimize neuromuscular mode amplitude peaking (roll ratchet tendency) without restricting roll control bandwidth (with resulting sluggish or PIO prone control). Author

N88-10793# National Aerospace Lab., Tokyo (Japan).
MEASUREMENTS IN THE FUNCTIONAL MOCK UP TEST OF THE NAL QSTOL AIRCRAFT CONTROL SYSTEM
AKIRA TADA, TOSHIO OGAWA, HIROYUKI YAMATO, TADAO UCHIDA, and NORIAKI OKADA Apr. 1987 30 p In JAPANESE; ENGLISH summary
(NAL-TR-928; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

In the functional mock up test of the NAL QSTOL research aircraft control system, measurements were planned and conducted with the intention of obtaining both real time results to support the development immediately, and reserved data suitable for academically rigorous and detailed analyses from various points of view. The physical quantities of 208 system variables were converted to analog voltage signals, and supplied from junction boxes to devices for recording and analysis. The system characteristics of primary interest in each test were investigated using chart recorders, a two-channel X-Y recorder, an FFT analyzer, and a monitoring unit of the on-board computers. A pre-processor unit of a minicomputer system converted 64 channels of the analog data to disk image digital data with a sampling rate of 100 Hx for each channel. Up to two hours of test data were temporarily stored

in the desk file, and then, as a part of near time processings, were transferred to magnetic tapes for preservation. A digital filtering and sampling technique, designated the Filtering Sample, was applied to the conversion of the pre-processor unit. The Filtering Sample showed a good anti-aliasing effect within a reasonable increment of the processing work load. Author

N88-10794# Aeronautical Research Labs., Melbourne (Australia).
A SURVEY OF AIRCRAFT INTEGRATED CONTROL TECHNOLOGY
R. D. HILL Sep. 1987 28 p
(AR-004-561; ARL-SYS-TM-95) Avail: NTIS HC A03/MF A01

Current design techniques applied to aircraft flight control systems have been surveyed and the increasing use of modern control theory in the control system design of experimental technology demonstrator aircraft is described. The modern control system design methodology is seen to be particularly suitable for application to the design of controllers for complex, multivariable aircraft systems which are composed of dynamically interacting subsystems. These will typically include the flight control, propulsion, and weapon systems. Some suggestions regarding the most appropriate form of future ARL involvement in this large and expanding area are made. Author

N88-10795# Cranfield Inst. of Tech., Bedford (England). College of Aeronautics.
A PRELIMINARY INVESTIGATION INTO THE FEASIBILITY OF IMPLEMENTING A DIRECT SIDEFORCE CONTROL SYSTEM ON THE ASTRA HAWK BY MEANS OF AN ACTIVE CONTROL SURFACE M.S. Thesis
V. A. ENGLISH Sep. 1986 196 p
(ETN-87-90924) Avail: NTIS HC A09/MF A01

A computer program to test the effect of an auxiliary surface by simulating the direct sideforce modes of motion, in order to estimate the maximum mode performance benefits, was developed. The program is written as a design tool, which incorporates data for the flight envelope from Mach 0.3 to 0.8 and from sea level to 36,000 ft, for the basic aircraft, with provision to add in derivatives due to the auxiliary surface. The program can be used to re-evaluate the behavior of the aircraft with auxiliary surface as the aerodynamics, geometry of the surface, position of the surface on the airframe, and hence derivatives of the surface are revised. ESA

N88-10798*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE APPLICATION OF EMULATION TECHNIQUES IN THE ANALYSIS OF HIGHLY RELIABLE, GUIDANCE AND CONTROL COMPUTER SYSTEMS
GERARD E. MIGNEAULT *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 12 p Jul. 1987
Avail: NTIS HC A07/MF A01 CSCL 01C

Emulation techniques can be a solution to a difficulty that arises in the analysis of the reliability of guidance and control computer systems for future commercial aircraft. Described here is the difficulty, the lack of credibility of reliability estimates obtained by analytical modeling techniques. The difficulty is an unavoidable consequence of the following: (1) a reliability requirement so demanding as to make system evaluation by use testing infeasible; (2) a complex system design technique, fault tolerance; (3) system reliability dominated by errors due to flaws in the system definition; and (4) elaborate analytical modeling techniques whose precision outputs are quite sensitive to errors of approximation in their input data. Use of emulation techniques for pseudo-testing systems to evaluate bounds on the parameter values needed for the analytical tachniques is then discussed. Finally several examples of the application of emulation techniques are described. Author

N88-10799# Marconi Avionics Ltd., Rochester (England). Combat Aircraft Controls Div.
SOME APPROACHES TO THE DESIGN OF HIGH INTEGRITY SOFTWARE
J. T. SHEPHERD, D. J. MARTIN, and R. B. SMITH *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 14 p Jul. 1987 Sponsored by Ministry of Defence, United Kingdom
Avail: NTIS HC A07/MF A01

As the complexity of aircraft systems has increased and the performance requirements for such aircraft have become more demanding the number of safety critical systems carried has increased. This allied to the preponderance of digital systems on board the aircraft has meant that the software requirements of safety critical systems have become one of the key items in the development of new aircraft. In the early days of high integrity systems analog techniques were used and a variety of redundancy techniques developed to cope with the need to obtain the required level of integrity from system elements whose inherent reliability was low. With the advent of digital systems it is necessary to consider how much integrity can be achieved with system software so that the total integrity of a safety critical system can be maintained. This can be achieved by fault avoidance or fault tolerance. To date the former has been the main method used to achieve high integrity software. However, fault avoidance to be effective must assume an error free system, which is near impossible to achieve. Fault avoidance is combined with fault tolerance, which adjusts the system to its inherent errors, and is added to assure greater reliability. F.M.R.

N88-10800# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (West Germany). Inst. for Flight System Dynamics.
ROBUST CONTROL SYSTEM DESIGN
J. ACKERMANN *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 14 p Jul. 1987 Previously announced as N81-11275
Avail: NTIS HC A07/MF A01

The short period longitudinal mode of an F 4-E with horizontal canards is unstable in subsonic flight and insufficiently damped at supersonic speed. The control system has to provide acceptable pole locations according to military specifications for flying qualities. A fixed gain controller using three paralleled gyros is designed, such that the pole region requirements in four typical flight conditions are robust with respect to a gain reduction to one third. Thus nothing bad happpens immediately when one or two gyros fail. Failure detection and redundancy management may be performed at a higher hierarchical level, and not necessarily extremely fast. The use of accelerometers or air data sensors for angle of attack or dynamic pressure is totally avoided in this concept and no gain scheduling is necessary. The design for robustness with respect to different flight conditions and sensor failures is performed by a novel parameter space design tool. Author

N88-10801*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RELIABILITY MODELING OF FAULT-TOLERANT COMPUTER BASED SYSTEMS
SALVATORE J. BAVUSO *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 16 p Jul. 1987
Avail: NTIS HC A07/MF A01 CSCL 01C

Digital fault-tolerant computer-based systems have become commonplace in military and commercial avionics. These systems hold the promise of increased availability, reliability, and maintainability over conventional analog-based systems through the application of replicated digital computers arranged in fault-tolerant configurations. Three tightly coupled factors of paramount importance, ultimately determining the viability of these systems, are reliability, safety, and profitability. Reliability, the major driver affects virtually every aspect of design, packaging, and field operations, and eventually produces profit for commercial applications or increased national security. However, the utilization

of digital computer systems makes the task of producing credible reliability assessment a formidable one for the reliability engineer. The root of the problem lies in the digital computer's unique adaptability to changing requirements, computational power, and ability to test itself efficiently. Addressed here are the nuances of modeling the reliability of systems with large state sizes, in the Markov sense, which result from systems based on replicated redundant hardware and to discuss the modeling of factors which can reduce reliability without concomitant depletion of hardware. Advanced fault-handling models are described and methods of acquiring and measuring parameters for these models are delineated. Author

N88-10803# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.

OPTIMAL DETECTION OF SENSOR FAILURES IN FLIGHT CONTROL SYSTEMS USING DETERMINISTIC OBSERVERS

NORBERT STUCKENBERG *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 21 p Jul. 1987

Avail: NTIS HC A07/MF A01

A failure detection scheme for sensors of a flight control system is presented. Based on analytic redundancy a duplex sensor configuration provides the fail-operational capability of a conventional triplex sensor system. This is achieved by using deterministic observers. It is shown how the performance of the failure detection scheme can be determined. With respect to this performance criterion the optimal observer is derived. Thus, the performance eventually achievable by an optimal failure detection scheme is also described. The operational feasibility of the proposed concept is demonstrated by flight test results. Author

N88-10804# Verilog S.A., Toulouse (France).

ASSESSMENT OF SOFTWARE QUALITY FOR THE AIRBUS A310 AUTOMATIC PILOT

R. TROY and C. BALUTEAU (*Societe Francaise d'Equipements* pour la Navigation Aerienne, Velizy-Villacoublay, France) *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control System 13 p Jul. 1987

Avail: NTIS HC A07/MF A01

As for the whole of the Automatic Flight Control System, the automatic pilot for the AIRBUS is a computer system with high criticality. In order to assess the quality of the software, a number of observations and measurements have been made during the development cycle. A general method of evaluation, the data collected, and some evaluation results are presented. The aims of this analysis are to assess the impact of development constraints on the quality of the product and to evaluate its operational reliability. The results show conditions in which software may be adversely affected by modifications. In particular, they make it possible to appreciate the quality of design, the effectiveness of the verification and validation processes, and the flexibility of the software. The last part gives a tentative example of operational reliability evaluation, taking into consideration the complexity of the functions and the mission profile. Author

N88-10805*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

FLIGHT TEST OF A RESIDENT BACKUP SOFTWARE SYSTEM

DWAIN A. DEETS, WILTON P. LOCK, and VINCENT A. MEGNA (Draper, Charles Stark Lab., Inc., Cambridge, Mass) *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 9 p Jul. 1987 Previously announced as N86-19325

Avail: NTIS HC A07/MF A01

A new fault-tolerant system software concept employing the primary digital computers as host for the backup software portion has been implemented and flight tested in the F-8 digital fly-by-wire airplane. The system was implemented in such a way that essentially no transients occurred in transferring from primary to backup software. This was accomplished without a significant increase in the complexity of the backup software. The primary digital system was frame synchronized, which provided several advantages in implementing the resident backup software system. Since the time of the flight tests, two other flight vehicle programs have made a commitment to incorporate resident backup software similar in nature to the system described here. Author

N88-10806# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

KNOWLEDGE BASED CONCEPTS AND ARTIFICIAL INTELLIGENCE: APPLICATIONS TO GUIDANCE AND CONTROL

Aug. 1987 145 p Lectures held in Ottawa, Ontario, 10-11 Sep., in Monterey, Calif., 14-15 Sep., in Delft, Netherlands, 12-13 Oct., and in Lisbon, Portugal, 15-16 Oct. 1987

(AGARD-LS-155; ISBN-92-835-1588-7) Avail: NTIS HC A07/MF A01

The intent of this lecture series was to clearly describe what artificial intelligence techniques mean with respect to guidance and control applications, to offer some concrete examples of applications to the maintenance area, some more speculative examples of applications to actual guidance and control tasks, and a projection of possible directions for the future.

N88-10807# General Electric Co., Binghamton, N.Y.

OVERVIEW OF AGARD LECTURE SERIES NO. 155: KNOWLEDGE-BASED CONCEPTS AND ARTIFICIAL INTELLIGENCE APPLICATIONS TO GUIDANCE AND CONTROL

RIHCARD PAUL QUINLIVAN *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 5 p Aug. 1987

Avail: NTIS HC A07/MF A01

Several lectures dealing with artificial intelligence (AI) applications to guidance and control are reviewed. The use of various forms of AI techniques to help solve problems related to guidance and control is a subject of current interest. Most, if not all, of the practical applications utilize knowledge-based techniques to create so-called 'expert systems'. These systems seem to offer solutions to guidance and control problems that have a large judgment content. Examples include maintenance systems and real-time, decision aiding systems. Author

N88-10808# Analytic Sciences Corp., Reading, Mass.

AI EXPERT SYSTEM TECHNOLOGY ISSUES FOR GUIDANCE AND CONTROL APPLICATIONS

HAROLD L. JONES *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 7 p Aug. 1987

Avail: NTIS HC A07/MF A01

A perspective is provided on a set of technical issues, which, if unresolved, could limit the capability and acceptability of expert systems decision making for avionics applications. Examples from ongoing expert system development programs are used to illustrate likely architectures and applications of future intelligent avionics systems. Author

N88-10811# Lear Siegler, Inc., Grand Rapids, Mich. Instrument and Avionic Systems Div.

APPLICATION OF KNOWLEDGE-BASED TECHNIQUES TO AIRCRAFT TRAJECTORY GENERATION AND CONTROL

MICHAEL W. BIRD *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p Aug. 1987

(Contract F33615-84-C-3626)

Avail: NTIS HC A07/MF A01

A concept that embeds the knowledge-based techniques in a trajectory generation and control system is defined. The control system is called the Unified Trajectory control System (UTCS). The objective of the system is to aid the pilot when operating in the intense threat environment projected for the 1990's. The UTCS has an architecture of independent trajectory generation elements whose operations are integrated by a knowledge-based system.

This artificial intelligence (AI) technique utilizes production rules, an interface engine, and a system of frames for communicating with the trajectory generation elements. Author

N88-10818*# National Aeronautics and Space Administration, Washington, D.C.
INVESTIGATION OF CONTROL LAW FOR ACTIVE FLUTTER SUPPRESSION
WEIPENG WANG, ZHONGQUAN GU, and DEMAO ZHU Nov. 1987 18 p Transl. into ENGLISH from Acta Aeronautica et Astronautica Sinica, People's Republic of China, v. 7, Dec. 1986 p 566-574 Original language document was announced in IAA as A87-29607 Transl. by Kanner (Leo) Associates, Redwood City, Calif. Prepared by Nanjing Aeronautical Coll., People's Republic of China
(Contract NASW-4005)
(NASA-TT-20126; NAS 1.77:20126) Avail: NTIS HC A03/MF A01 CSCL 01C

Discussed is the technology of active flutter suppression research by the use of the wind-tunnel model of a delta wing with low aspect ratio. The research includes the establishment of a mathematical model for the servo-aeroelastic system, and the synthesis and analysis of sub-optimal output feedback control laws for active flutter suppression. Author

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RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A88-10044
TESTING OF AIRCRAFT ELECTRICAL EQUIPMENT [ISPYTANIE AVIATSIONNOGO ELEKTROOBORUDOVANIIA]
VALERII NIKOLAEVICH BERDNIKOV Moscow, Izdatel'stvo Mashinostroenie, 1986, 192 p. In Russian. refs

Methods for the testing of aircraft electrical equipment, both at the stage of manufacture and during its development, are presented in a systematic manner. Attention is given to the technical requirements for the electrical equipment of aircraft, classification of test procedures, test equipment, technical documentation, and safety engineering during testing. The discussion covers testing of electrical, acoustic, and vibration characteristics, mechanical testing, environmental testing, and reliability testing. V.L.

A88-10156
LOW COST WINDOWLESS COCKPIT RESEARCH VEHICLE
ROSS E. AILSLIEGER and DAVID T. PALMER (Boeing Military Airplane Co., Wichita, KS) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 45-49.
(SAE PAPER 861755)

A commercial extension boom type forklift was modified for operation from a remote crew station. Two interchangeable cockpits were fabricated: (1) a generic helicopter cockpit with large windows and (2) a windowless cockpit with three television scenes projected on a panoramic display for outside vision. The vehicle is operated by a side-stick controller and a 'collective' lever. The goal was to develop a low-cost means to conduct research into windowless aircraft operations. The vehicle tests have begun and will be expanded as the cockpit electronics are developed. Author

A88-11470
FLIGHT SIMULATION
J. M. ROLFE, ED. (Ministry of Defence, London, England) and K. J. STAPLES, ED. (Royal Aircraft Establishment, Bedford, England) Cambridge and New York, Cambridge University Press, 1986, 294 p. No individual items are abstracted in this volume.

Theoretical and practical aspects of flight simulation (FS) are examined in an introductory textbook. Chapters are devoted to the fundamental principles and history of FS; mathematical models of FS; the simulation of aircraft systems; structures and cockpit systems; motion systems; visual systems; instructors' facilities; integration, testing, and acceptance; the simulator as a research tool; and the simulator as a training device. Diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A88-12488
DYNAMIC WIND TUNNEL BALANCES IN THE DFVLR SUBSONIC WIND TUNNEL IN BRAUNSCHWEIG [DYNAMISCHE WINDKANALWAAGEN AM NIEDERGESCHWINDIGKEITS-WINDKANAL DER DFVLR IN BRAUNSCHWEIG]
G. KAUSCHE (DFVLR, Brunswick, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, May-June 1987, p. 185-187. In German. refs

Two dynamic balances for measuring dynamic derivatives in wind tunnels of the DFVLR subsonic wind tunnel in Braunschweig, the Mobile Oscillatory Derivative Balance (MODB) and the Rotary Derivative Balance (RDB), are briefly described. Information is presented on the measurement methods used, recent improvements and operations, and the attainable results. It is shown that the MODB, due to its mobility, has a higher productivity than the RDB. C.D.

N88-10041# Royal Aircraft Establishment, Farnborough (England).
INVESTIGATION OF THE SUITABILITY OF THE 8FT X 6FT TRANSONIC WIND-TUNNEL FOR AEROACOUSTIC RESEARCH ON PROPELLERS
W. J. G. TREBBLE Jan. 1987 31 p
(RAE-TM-AERO-2093; BR102327; ETN-87-90697) Avail: NTIS HC A03/MF A01

The 8ft x 6ft transonic wind tunnel is shown to have a very high noise level, but near field noise signals from a 0.73 m diameter propeller are readily detected above the tunnel background noise at airspeeds up to at least Mach 0.6. Unfortunately the hard walls of the tunnel working chamber produce echoes which interfere with the propeller noise signals. For the facility to be used for aeroacoustic research it is necessary to either develop complex analytical methods using multiple microphone techniques or to line the interior walls of the working chamber with acoustic blankets. ESA

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ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A88-13086#
AN OVERVIEW OF SPACE AND AIRCRAFT NAVIGATION
TATSUKICHI KOSHIO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 396, 1987, p. 2-8. In Japanese. refs

Recent developments connected with the utilization of navigation satellites for the GPS and for air traffic control are reviewed. Consideration is given to the airspace management system and to the operating principles of STAR GPS. The future prospects of navigation satellites are assessed. S.H.

N88-10078# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. for Experimental Fluid Mechanics.
ANALYSIS OF FREE MOLECULAR EFFECTS ON THE ATTITUDE OF SATELLITES IN GEOSTATIONARY TRANSFER ORBIT. PART 2: FORCE AND TORQUE MEASUREMENT IN FREE MOLECULAR WIND TUNNEL TESTS
G. KOPPENWALLNER and H. LEGGE Paris, France ESA 1986 50 p
(Contract ESOC-5762/83-D-IM(SC))
(DFVLR-IB-222-86-A-07; ESA-CR(P)-2408-VOL-2; ETN-87-90545)
Avail: NTIS HC A03/MF A01

In order to determine the center of pressure of a satellite in addition to lift, drag, and moment coefficients, the feasibility of combined force and torque measurements in free molecular wind tunnel experiments is analyzed. An electromagnetic two-component balance seems suitable for this task. ESA

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A88-10031* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE EFFECT OF VARIATIONS OF COBALT CONTENT ON THE CYCLIC OXIDATION RESISTANCE OF SELECTED NI-BASE SUPERALLOYS
CHARLES A. BARRETT (NASA, Lewis Research Center, Cleveland, OH) IN: Alternate alloying for environmental resistance; Proceedings of the Symposium, New Orleans, LA, Mar. 2-6, 1986 . Warrendale, PA, Metallurgical Society, Inc., 1987, p. 211-231. Previously announced in STAR as N86-31702.

Cobalt levels were systematically varied in the Ni-base turbine alloys U-700 (cast), U-700m (PM/HIP), Waspaloy, Mar-M-247, In-738, Nimonic-115, U-720, and SX-R-150. the cobalt levels ranged from 0 wt pct to the nominal commercial content in each alloy. the alloys were tested in cyclic oxidation in static air at 1000, 1100 and 1150 C for 500, 200, and 100 hr, respectively. An oxidation attack parameter, Ka, derived from the specific weight change versus time data was used to evaluate the oxidation behavior of the alloys along with X-ray diffraction analysis of the surface oxides. The alloys tend to form either Cr2O3/chromite spinel or Al2O3/aluminate spinel depending on the Cr/Al ratio in the alloys. Alloys with a ratio of 3.5 or higher tend to favor the Cr oxides while those under 3.0 form mostly Al oxides. In general the Al2O3/aluminate spinel forming alloys have the better oxidation resistance. Increased cobalt content lowers the scaling resistance of the higher Cr allys while a 5.0 wt pct Co content is optimum for the Al controlling alloys. The refractory metals, particularly Ta, appear beneficial to both types of oxides, perhaps due to the formation of the omnipresent trirutile Ni(Ta, Cb, Mo, W)2O6. Both scales break down as increasing amounts of NiO are formed.
Author

A88-10180
APPLICABILITY OF A DIFFUSION COMBUSTION MODEL TO THE ANALYSIS OF SUPERSONIC TURBULENT REACTING JETS [O PRIMENIMOSTI MODELI DIFFUZIONNOGO GORENIIA K RASCHETU SVERKHZVUKOVYKH TURBULENTNYKH REAGIRUIUSHCHIKH STRUI]
S. I. BARANOVSKII and V. A. PERMINOV Fizika Goreniia i Vzryva (ISSN 0430-6228), vol. 23, May-June 1987, p. 85-88. In Russian. refs

The combustion of a supersonic turbulent jet of hydrogen in air was modeled using boundary layer and diffusion combustion approximations. The model included the effect of concentration pulsations on the mean values of the thermodynamic quantities. The results were compared with measurements obtained in an experiment with a zero ignition delay. It is found that, although an analysis including the effect of pulsations gives better results than a quasi-laminar approach, the final rates of chemical reactions must be considered to correctly model combustion in supersonic flow. V.L.

A88-10872
FLUIDS FOR DEICING AIRCRAFT SURFACES
Aerospace Engineering (ISSN 0736-2536), vol. 7, Sept. 1987, p. 21-23.

The types of deicing/antiicing fluids and removal procedures currently used are discussed. The removal procedure involves spray applications of aircraft deicing fluids, hot water, or a mixture of both; the procedures for applying the fluids on the aircraft are described. The deicing fluids used in North America are 80-90 percent ethylene glycol and 10-20 percent water corrosion inhibitors, wetting agents, and other glycols. The two types of fluids used by European airlines are categorized by material requirements, freezing points, rheological properties, and antiicing performance characteristics. Type I has a minimum of 80 percent glycol and is used for deicing operations, and type II contains a minimum of 50 percent glycol and is applied in deicing and antiicing operations. The U.S. military utilizes two types of fluids that are basically the same except that the type II fluid contains sodium salt of tolytriazole. I.F.

A88-11001#
COMBUSTION GAS PROPERTIES. III - PREDICTION OF THE THERMODYNAMIC PROPERTIES OF COMBUSTION GASES OF AVIATION AND DIESEL FUELS
OEMER L. GUELDER (National Research Council of Canada, Div. of Mechanical Engineering, Ottawa) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-49)

Empirical formulas are presented by means of which the specific heat, mean molecular weight, density, and specific heats ratio of aviation fuel-air and diesel fuel-air systems can be calculated as functions of pressure, temperature, equivalence ratio, and hydrogen-to-carbon atomic ratio of the fuel. Comparisons of the results from the proposed formulas with the results obtained from a chemical equilibrium code show that the mean absolute error in predicted specific heat is 0.8 percent, and that for molecular weight is 0.25 percent. These formulas provide a very fast and easy means of predicting the thermodynamic properties of combustion gases as compared to detailed equilibrium calculations, and they are also valid for a wide range of complex hydrocarbon mixtures

and pure hydrocarbons as well as aviation and diesel fuels.
Author

A88-11002#
PACK CEMENTATION COATINGS FOR SUPERALLOYS - A REVIEW OF HISTORY, THEORY, AND PRACTICE
G. W. GOWARD and L. W. CANNON (Turbine Components Corp., Branford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-50)

Nickel- and cobalt-base superalloy blades and vanes in the hot sections of all gas turbines are coated to enhance resistance to hot corrosion. Pack cementation aluminizing is the most widely used coating process. Corrosion resistance of aluminide coatings can be increased by modification with chromium, platinum, or silicon. Chromium diffusion coatings can be used at lower temperatures. Pack cementation and related diffusion coatings serve well for most aircraft engine applications. The trend for industrial and marine engines is more toward the use of overlay coatings because of the greater ease of designing these to meet a wide variety of corrosion conditions. Author

A88-11010#
PREDICTION OF NO AND CO DISTRIBUTION IN GAS TURBINE COMBUSTORS
SHINICHI KAJITA (Kawasaki Heavy Industries, Ltd., Akashi, Japan) and RYUICHI MATUMOTO (Kobe University, Japan) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-63)

An experimental and numerical investigation was performed to assess the performance of a procedure for the prediction of NO and CO formed in gas turbine combustors. The experimental procedure consists of measuring the flow, temperature, and pollutant fields in a premixed-gas turbine combustor. The profiles of velocity, temperature, and concentrations of NO and CO within the combustor are predicted by means of a three-dimensional model in which the k-epsilon two-dimensional model is used as a turbulence model, and in which the effect of turbulence on the reaction rate is taken into account by employing the modified eddy-break-up model. Although qualitative agreement between the predicted and measured values was fairly good, quantitative agreement was not obtained. R.R.

A88-11052#
PREDICTION OF COMBUSTION PERFORMANCE OF AVIATION KEROSINES USING A NOVEL PREMIXED FLAME TECHNIQUE
D. M. CARRIER and R. J. WETTON (Shell Research, Ltd., Thornton Research Centre, Chester, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. Research supported by the Ministry of Defence of England. refs
(ASME PAPER 87-GT-125)

A novel method for predicting aviation fuel combustion performance has been developed in which the sooting point of a premixed flame is detected automatically. Comparisons with full-scale combustor data confirm that the technique is a more realistic index of combustion quality than Smoke Point or hydrogen content. Author

A88-11086#
INVESTIGATION OF HIGH-ALTITUDE IGNITION PERFORMANCE OF SEVERAL CHINESE JET FUELS WITH DIFFERENT PROPERTIES
NENG-KUEN CHEN (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-178)

Investigation of high-altitude ignition performance of five Chinese jet fuels with different properties has been conducted at a simulated-altitude facility. Jet fuels were tested in a small pilot combustion chamber taken from an existing engine. Test results show that the lower the fuel density, the better the high-altitude ignition performance. Test results also show that the prevailing theoretical model of spark ignition is reasonable. Author

A88-11095#
APPLICATIONS OF CERAMIC COATING ON THE TURBINE BLADES OF THE AGTJ-100B
KAZUO UCHIDA, AKINORI KOGA, KIYOMI TESHIMA, and MASASHI ARAI (Engineering Research Association for Advanced Gas Turbines, Tokyo, Japan) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-190)

The high inlet gas temperature (1673 K) of the AGTJ-100B advanced high-temperature high-pressure turbine (developed for an energy conservation pilot plant in Japan) requires superior thermal insulation; a ceramic thermal barrier coating (TBC) was developed for this purpose. This paper describes a series of tests that evaluated the thermal barrier performance and durability of the TBC. The 0.2-0.3 mm thick coating (including the 0.1-mm-thick bond coat) is made of yttria-stabilized zirconia (ZrO_2-Y_2O_3); the bond coat material is MCrAlY. The blade profile platforms and shrouds are fully covered with the TBC in order not to expose the coating edge to a high temperature and high-speed gas flow. Test results are included. I.S.

A88-11146
HYDROGEN IN AIR TRANSPORTATION - FEASIBILITY STUDY FOR ZURICH AIRPORT, SWITZERLAND
H. P. ALDER (Eidgenoessisches Institut fuer Reaktorforschung, Wuerenlingen, Switzerland) International Journal of Hydrogen Energy (ISSN 0360-3199), vol. 12, no. 8, 1987, p. 571-585. refs

As a member of the Ad Hoc Executive Group (AHEG) for 'Hydrogen in Air Transportation', the Swiss Group, composed of representatives from industry, Swissair, the utilities and the government, decided to carry out a study on the feasibility of refueling one cargo-aircraft per day with 15 to 30 t of liquid hydrogen (LH2). For the mission California-Europe-Saudi Arabia, Zurich Airport is well suited as a European base, provided the following option is chosen: electrolytic hydrogen production, liquefaction and storage at one site on the Airport. For the demonstration phase the existing infrastructure can absorb the pilot installations without additional secondary investment. For a commercial operation, however, the economics of the LH2 production has to be improved and the Airport infrastructure (land, power supply, cooling water, runways) has to be expanded. Author

A88-12414
COMPOSITE DIRECTIONS AT KAMAN
PAUL F. MALONEY (Kaman Aerospace Corp., Bloomfield, CT) Vertiflite (ISSN 0042-4455), vol. 33, Sept.-Oct. 1987, p. 26-31.

An account is given of the interdisciplinary approach employed by a major composite material aerospace structures manufacturer in the design, analysis, material selection/characterization, tool design, and nondestructive testing of all-composite helicopter main rotor blades. The K747 composite main rotor blade program for the U.S. Army's AH-1 Cobra helicopter, initiated in 1975, has yielded over 2600 such blades to date. Attention is given to the SH-2F/G composite main rotor blade, which employs many features of the AH-1 blade but represents the next generation of computer-aided design, tooling, and fabrication techniques; the use of solid aluminum mandrels and matched steel molds yields a dimensionally exact product with excellent airfoil contour fidelity. O.C.

A88-12415
BUILDING ON A SUCCESSFUL TRADITION - COMPOSITES AT MDHC
DEAN C. BORGMAN (McDonnell Douglas Helicopter Co., Mesa, AZ) Vertiflite (ISSN 0042-4455), vol. 33, Sept.-Oct. 1987, p. 32-36.

A development history and current status report is presented for the advanced aerospace composite structures products of a major U.S. helicopter manufacturer. Beginning with composite main

rotor and flexbeam tail rotor blades for the AH-64 helicopter, work proceeded to Kevlar 29-reinforced composite blades and reinforced thermosetting resin-based AH-1 helicopter fuselage structures. More recently, attention has been given to thermoplastic matrix composites for the AH-64 military helicopter and for the aerodynamic fairing secondary structures of the C-17 airlifter. O.C.

A88-12626
CONFERENCE ON MECHANICAL BEHAVIOR OF SUPERALLOYS, LONDON, ENGLAND, JUNE 10, 11, 1986, SELECTED PAPERS
Conference sponsored by the Royal Society. Materials Science and Technology (ISSN 0267-0836), vol. 3, Sept. 1987, 129 p. For individual items see A88-12627 to A88-12636.

The present conference on the development status of superalloy compositions and processing methods for such applications as gas turbine blades and disks gives attention to the mechanical property requirements and creep behavior of aircraft gas turbine materials, the low cycle fatigue behavior and the fatigue crack growth of superalloy blade materials at elevated temperatures, and novel materials for industrial gas turbines. Also discussed are recent developments in gas turbine disk materials, gas turbine superalloy component service life-estimation methods, fatigue crack propagation in Ni-based superalloys (with attention to the effects of microstructure, load ratio, and temperature), the effects of environment on the crack growth behavior of superalloys under various loading conditions, and high-temperature sheet materials for gas turbine applications. O.C.

A88-12628
MECHANICAL PROPERTY REQUIREMENTS FOR AERO GAS TURBINE MATERIALS
M. J. WEAVER (Royal Aircraft Establishment, Farnborough, England) (Royal Society, Conference on Mechanical Behaviour of Superalloys, London, England, June 10, 11, 1986) Materials Science and Technology (ISSN 0267-0836), vol. 3, Sept. 1987, p. 695-700.

The outstanding performance of current military and civil aero gas turbine engines is linked closely to the way in which modern design and manufacturing techniques have become totally integrated with materials designed specifically for operation within the hostile environment of a gas turbine. Advanced titanium alloys are used extensively throughout the compressor and nickel-base superalloys dominate materials application in the turbine. In spite of current achievements, the engine designer is still under severe competitive pressure to improve engine performance still further and this will inevitably lead to even more demanding material requirements. The present paper outlines the continuing trends in engine development and describes the impact these are having on materials technology in general and the mechanical property requirements of nickel-base superalloys in particular. Author

A88-12632
DEVELOPMENTS IN DISC MATERIALS
F. SCZERZENIE and G. E. MAURER (Special Metals Corp., New Hartford, NY) (Royal Society, Conference on Mechanical Behaviour of Superalloys, London, England, June 10, 11, 1986) Materials Science and Technology (ISSN 0267-0836), vol. 3, Sept. 1987, p. 733-742. refs

Discs have always been the life- and reliability-limiting components of the gas turbine engine. Progress in disc materials development has been enhanced through the interaction of superalloy materials and metallurgical process development. Disc service environment, property requirements, and physical metallurgy are reviewed. Historically, the introduction of stronger, more heat- and fatigue-resistant alloys has depended upon process developments such as vacuum induction melting, inert gas atomization, and thermomechanical processing. Current developments and future directions are reviewed, including new melting practices for the manufacture of clean metals, the forging of fatigue resistant microstructures and dual property discs. Author

A88-12635
HIGH-TEMPERATURE SHEET MATERIALS FOR GAS TURBINE APPLICATIONS
B. HICKS (Lucas Aerospace, Ltd., Fabrications Div., Burnley, England) (Royal Society, Conference on Mechanical Behaviour of Superalloys, London, England, June 10, 11, 1986) Materials Science and Technology (ISSN 0267-0836), vol. 3, Sept. 1987, p. 772-781. Research supported by the Ministry of Defence. refs

Aircraft gas turbines contain various sheet metal fabrications, such as combustion chambers, exhaust units, jet pipes, and reheat liners, which operate for long periods under arduous conditions. The properties required in a sheet alloy differ considerably from those of blades and vanes, so that alloys must be developed specifically for the purpose. The performance required of sheet alloys is discussed and current alloys are reviewed in terms of their fabrication, mechanical, and oxidation properties. Some recent developments are described in the field of thermal barrier coatings, dispersion strengthened alloys, and porous laminate materials. Author

A88-12786
BASIC CONCEPTS FOR BETTER HEAT PROTECTION SYSTEMS
K. FRITSCHER (DFVLR, Institut fuer Werkstoff-Forschung, Cologne, Federal Republic of Germany) Zeitschrift fuer Werkstofftechnik (ISSN 0049-8688), vol. 18, Aug. 1987, p. 265-277. refs

Several mechanisms concerning material degradation at high temperature are briefly reviewed. Oxidation kinetics, oxide structure, diffusion of species during oxidation, oxide scale formation, growth, and adhesion are considered. The hot corrosion mechanism is examined from the chemical and physicochemical standpoints. The improvement of corrosion resistance by superior oxide adhesion is emphasized. Protective measures against each type of degradation are discussed. Thermal barrier coatings (TBCs) for the protection of metal structures subjected to excessive heat and corrosion are addressed, and a viable TBC concept of fully dense ceramic coatings on suitable materials is presented. C.D.

N88-10159# Starck (Hermann C.) Berlin, Baden (West Germany).
DEVELOPMENT AND PRODUCTION OF NEW AND MODIFIED POWDERS FOR SPRAYED COATINGS AND COMPONENTS FOR SAVING IMPORTANT RAW MATERIALS Final Report, Jun. 1985
HEINZ ESCHNAUER, HELMUT MEINHARDT, and REINHOLD LUTZ Bonn, West Germany Bundesministerium fuer Forschung und Technologie Dec. 1986 90 p In GERMAN; ENGLISH summary Sponsored by Bundesministerium fuer Forschung und Technologie, West Germany
(BMFT-FB-T-86-129; ISSN-0340-7608; ETN-87-90561) Avail: NTIS HC A05/MF A01; Fachinformationszentrum, Karlsruhe, West Germany DM 18.50

Alloy systems for wear and corrosion protection were developed. Tough-hard, high chromium content composites of the type Mi-Cr-B-Si plus hard materials were investigated. These alloys, which are supplied to the users mainly as spray powders, set more stringent requirements on powder production that uses a vacuum-melt/inert-gas atomization process. The same applies to a developed high temperature solder, and alloys of the MCrAlY type. The atomizing plant was modified and improved with a view to the MCrAlY alloy, so that spray powders can be produced which fulfil aircraft industry specifications. ESA

N88-10192# Air Force Wright Aeronautical Labs., Hampton, Va.
COST SAVINGS POSSIBLE WITH AIR FORCE CONVERSION TO JP-8 AS ITS PRIMARY FUEL Summary Report, Jan. - Apr. 1987
CHARLES R. MARTEL May 1987 29 p
(AD-A183784; AFWAL-TR-87-2037) Avail: NTIS HC A03/MF A01 CSCL 05A

JP-4 has been the primary fuel for the USAF since 1951. However, in 1979 the USAF converted to JP-8 as its primary jet

fuel for its operations in Great Britain. Recently, the North Atlantic Treaty Organization (NATO) began the switch from JP-4 (F40) to JP-8 (F34) as its primary jet fuel. However, JP-4 continues to be the primary USAF jet fuel within the continental United States. The cost and manpower savings possible by converting from JP-4 to JP-8, as the primary jet fuel for the Air Force, are identified and estimated. The much lower volatility of JP-8, as compared to JP-4, accounts for the anticipated savings. For example, aircraft fuel systems must be purged prior to maintenance, and purging aircraft fuel systems that have contained JP-4 can take hours to days. With JP-8 purging may not even be necessary under most ambient temperatures. Another major savings is the reduced evaporation of JP-8, as compared to the more volatile JP-4. Finally, reduced fatalities and casualty losses resulting from ground and flight accidents are estimated. GRA

N88-10938*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
HIGH TEMPERATURE METAL MATRIX COMPOSITES FOR FUTURE AEROSPACE SYSTEMS
JOSEPH R. STEPHENS Oct. 1987 18 p Presented at the ASM International Composite Session, Cincinnati, Ohio, 13-15 Oct. 1987
(NASA-TM-100212; E-3821; NAS 1.15:100212) Avail: NTIS HC A03/MF A01 CSCL 11F

Research was conducted on metal matrix composites and intermetallic matrix composites to understand their behavior under anticipated future operating conditions envisioned for aerospace power and propulsion systems of the 21st century. Extremes in environmental conditions, high temperature, long operating lives, and cyclic conditions dictate that the test evaluations not only include laboratory testing, but simulated flight conditions. The various processing techniques employed to fabricate composites are discussed along with the basic research underway to understand the behavior of high temperature composites, and the relationship of this research to future aerospace systems. Author

N88-11169*# Connecticut Univ., Storrs.
CONSTITUTIVE MODELING OF SUPERALLOY SINGLE CRYSTALS WITH VERIFICATION TESTING
ERIC JORDAN and KEVIN P. WALKER (Engineering Science Software, Inc., Smithfield, R.I.) *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 277-286 Oct. 1985
(Contract NAG3-512)
Avail: NTIS HC A19/MF A01 CSCL 11F

The goal is the development of constitutive equations to describe the elevated temperature stress-strain behavior of single crystal turbine blade alloys. The program includes both the development of a suitable model and verification of the model through elevated temperature-torsion testing. A constitutive model is derived from postulated constitutive behavior on individual crystallographic slip systems. The behavior of the entire single crystal is then arrived at by summing up the slip on all the operative crystallographic slip systems. This type of formulation has a number of important advantages, including the prediction orientation dependence and the ability to directly represent the constitutive behavior in terms which metallurgists use in describing the micromechanisms. Here, the model is briefly described, followed by the experimental set-up and some experimental findings to date. Author

N88-11179*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPERIMENTAL VERIFICATION OF VAPOR DEPOSITION RATE THEORY IN HIGH VELOCITY BURNER RIGS
SULEYMAN A. GOEKOGLU (Case Western Reserve Univ., Cleveland, Ohio.) and GILBERT J. SANTORO *In its* Turbine Engine Hot Section Technology, 1985 p 383-390 Oct. 1985
Avail: NTIS HC A19/MF A01 CSCL 11F

The main objective has been the experimental verification of the corrosive vapor deposition theory in high-temperature, high-velocity environments. Towards this end a Mach 0.3 burner-rig appartus was built to measure deposition rates from salt-seeded (mostly Na salts) combustion gases on the internally cooled cylindrical collector. Deposition experiments are underway. Author

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A88-10017
PROBLEMS IN CONTINUUM MECHANICS WITH MIXED BOUNDARY CONDITIONS [ZADACHI MEKHANIKI SPLOSHNYKH SRED SO SMESHANNYMI GRANICHNYMI USLOVIIAMI]
VIKTOR MIKHAILOVICH ALEKSANDROV and EVGENII VENIAMINOVIC KOVALENKO Moscow, Izdatel'stvo Nauka, 1986, 335 p. In Russian. refs

Both classical results and new theoretical developments in the field of plane mixed problems are presented in a systematic manner. Particular attention is given to efficient analytical methods for solving mixed problems in continuum mechanics and their mathematical justification. The problems examined include mixed elasticity problems, such as contact interaction and stress concentration near cracks and thin inclusions, as well as problems in hydrodynamics, such as wing problems, glide and shock, and jet and cavitation flow problems. V.L.

A88-10170
COLOR DISPLAY TECHNOLOGY - AN OVERVIEW
J. ROBERT TRIMMIER (Sperry Corp., Phoenix, AZ) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 201-208. refs
(SAE PAPER 861692)

Recent advances in CRT technology are discussed including the shadow mask CRT for avionics displays, the beam index CRT, penetration tubes, and the liquid crystal/CRT field sequential color display. Consideration is also given to the projection display system, the color active matrix LCD, the vacuum fluorescent display, and the ac thin film electroluminescent display. It is believed that the shadow mask CRT will continue to dominate the home TV market.

A88-10497#
COUNTERROTATING DIFFERENTIAL CYLINDRICAL ROLLER BEARING DEVELOPMENT
BILL CRECELIUS (General Electric Co., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1843)

Advances in turbofan engine design have brought on the need for counterrotating main shaft roller bearings to operate to speeds greater than 3.7 million DN. To begin assimilating a data base, four bearings were tested for 25 hours each - one with round rings, a soft trilobe, a hard trilobe, and a hard bilobe. Internally, all bearings functioned equally well. However, severe fretting and ring turning developed at the inner ring shaft interface with all out-of-round bearings. Differential sumps pose some unique problems, but no problem could be linked to counterrotation. Computer program CYLFLEX was enhanced with lubrication and friction calculations to treat counterrotating roller bearings. Load distribution, change in clearance, component kinematics, cage slip, and frictional heat rate were all addressed. Author

A88-10570#
MULTIGRID SOLUTION OF THE EULER EQUATIONS ON UNSTRUCTURED AND ADAPTIVE MESHES
D. MAVRIPLIS and A. JAMESON (Princeton University, NJ) University of Colorado and USAF, Copper Mountain Conference on Multigrid Methods, 3rd, Copper Mountain, CO, Apr. 6-10, 1987, Paper. 23 p. refs

A multigrid algorithm for application to a sequence of completely unstructured and unrelated meshes is discussed, and solutions for the supercritical flow over a two-element airfoil system are presented. A Delaunay algorithm (Weatherill, 1985), in which the distribution of mesh points is either determined by conformal mapping techniques or by adaptive refinement of the previous coarser mesh, is used to generate the meshes. Although the finest mesh used in the adaptive refinement sequence contains about 1/4 as many mesh points as that used in the global refinement sequence, the calculated force coefficients for both solutions are found to compare closely. R.R.

A88-10628
THREE-DIMENSIONAL FLOW IN A ROTOR - A STRICTLY THREE-DIMENSIONAL CALCULATION OF FLOWS IN TURBOMACHINES USING THE S1-S2 METHOD [ECOULEMENT TRIDIMENSIONNEL DANS UNE ROUE - CALCUL EFFECTIVEMENT TRIDIMENSIONNEL DES ECOULEMENTS DANS LES TURBOMACHINES PAR LA METHODE S1-S2]
D. BUISINE and P. MICHEAU (Lille I, Universite, Villeneuve-d'Ascq, France) Journal de Mecanique Theorique et Appliquee (ISSN 0750-7240), vol. 6, no. 4, 1987, p. 525-546. In French. refs

The restrictions which are traditionally imposed to overcome the instability of the S1-S2 method are investigated, and a strictly three-dimensional technique for the coupling of the S1-S2 method is proposed which uses only the local equations and the boundary conditions. The technique takes into account important processes in the design of blade shapes, and it is demonstrated with the examples of an axial compressor and a rotor with a helical blade shape. The present method is found to accurately model the interactions between processes including the secondary effects, the local radial equilibrium, and the downstream equilibrium between the jets, in addition to being able to predict the appearance of processes which degrade rotor performance. R.R.

A88-10726
EXTENDED SYSTEMS OF VARIABLE STRUCTURE WITH MOBILE RADIO-COMMUNICATION OBJECTS [PROTIAZHENNYE SISTEMY IZMENIAIUSHCHEISIA STRUKTURY S PODVIZHNYMI OB'EKTAMI RADIOSVIAZI]
N. O. VARGANOV, V. V. VOSKOBOINIKOV, and A. F. MEVIS Radiotekhnika (ISSN 0033-8486), June 1987, p. 3-6. In Russian.

Relationships are obtained for the fail-safe operation of extended systems of variable structure with mobile radio-communication objects. These relationships can be applied to the study of extended communication lines in civil-aviation systems. B.J.

A88-10969*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
USE OF A LIQUID-CRYSTAL AND HEATER-ELEMENT COMPOSITE FOR QUANTITATIVE, HIGH-RESOLUTION HEAT-TRANSFER COEFFICIENTS ON A TURBINE AIRFOIL INCLUDING TURBULENCE AND SURFACE-ROUGHNESS EFFECTS
S. A. HIPPENSTEELE, L. M. RUSSELL, and F. J. TORRES (NASA, Lewis Research Center, Cleveland, OH) IN: Pressure temperature measurements. New York, American Society of Mechanical Engineers, 1987, p. 105-120. Previously announced in STAR as N87-22181. refs

Local heat transfer coefficients were measured along the midchord of a three-times-size turbine vane airfoil in a static cascade operated at room temperature over a range of Reynolds numbers. The test surface consisted of a composite of commercially available materials: a Mylar sheet with a layer of cholestric liquid crystals, which change color with temperature, and a heater made of a polyester sheet coated with vapor-deposited gold, which produces uniform heat flux. After the initial selection and calibration of the composite sheet, accurate, quantitative, and continuous heat transfer coefficients were mapped over the airfoil surface. Tests were conducted at two free-stream turbulence intensities: 0.6 percent, which is typical of wind tunnels; and 10 percent, which is typical of real engine conditions. In addition to a smooth airfoil, the effects of local leading-edge sand roughness were also examined for a value greater than the critical roughness. The local heat transfer coefficients are presented for both free-stream turbulence intensities for inlet Reynolds numbers from 1.20 to 5.55 x 10 to the 5th power. Comparisons are also made with analytical values of heat transfer coefficients obtained from the STAN5 boundary layer code. Author

A88-10979#
INFLUENCE OF THE REYNOLDS NUMBER ON THE PERFORMANCE OF CENTRIFUGAL COMPRESSORS
R. A. STRUB (Gebrueder Sulzer AG, Winterthur, Switzerland), L. BONCIANI (Nuovo Pignone S.p.A., Florence, Italy), C. J. BORER (Dresser Industries, Inc., Waukesha, WI), M. V. CASEY (Sulzer Escher Wyss, Ltd., Zurich, Switzerland), S. L. COLE (Ingersoll-Rand Co., Bristol, VA) et al. ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. refs
(ASME PAPER 87-GT-10)

Improved formulas are presented for the correction of the efficiency, the head, and the flow as influenced by the Reynolds number variation between workshop tests and specified conditions, carried out with the same machine. Tests have shown that a sufficiently good correlation between measured and predicted values can be obtained with the proposed formulas. In addition, a proposal is made for the allowable range, taking into account the inherent limitations for accurate testing at low Reynolds numbers. It is recommended that the proposed formulas and allowable range be reviewed by the ASME, the ISO, or any other associations for adoption in revised test codes for centrifugal compressors. Author

A88-10992#
MOMENTUM EXCHANGES AND ENERGY TRANSFERS IN CROSS FLOW FANS
JOSEPH MAZUR (Eaton Corp., Southfield, MI) and TRILOCHAN SINGH (Wayne State University, Detroit, MI) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-32)

An experimental investigation of the flow in a cross flow fan at three operating conditions is reported. Velocity and pressure maps for the flow field are presented along with a determination of the momentum exchanges and energy transfers between the blading and the flow field regions. Author

A88-11000*# Aerometrics, Inc., Mountain View, Calif.
EXPERIMENTS ON SPRAY INTERACTIONS IN THE WAKE OF A BLUFF BODY
R. C. RUDOFF, M. J. HOUSER, and W. D. BACHALO (Aerometrics, Inc., Mountain View, CA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 9 p. refs
(Contract NAS3-24844)
(ASME PAPER 87-GT-48)

The dynamics of spray drop interaction within the turbulent wake of a bluff body were investigated using the Aerometrics Phase Doppler Particle Analyzer that determines both drop size and velocity. Detailed measurements obtained included spray drop size, axial and radial velocity, angle of trajectory, and size-velocity correlations. The gas-phase flow field was also ascertained via the behavior of the smallest drops. Results showed dramatic differences in drop behavior when interacting with turbulence for the various size classes. Small drops were recirculated in a pair of toroidal vortices located behind the bluff body, whereas the larger drops followed the general direction of the spray cone angle.

The spray field interaction illustrated by these data casts some doubt on attempts to describe sprays via simple integral quantities such as the Sauter mean diameter. Author

A88-11016#
SEALING OF A SHROUDED ROTOR-STATOR SYSTEM WITH PRE-SWIRL COOLANT
Z. B. EL-OUN, P. H. NELLER, and A. B. TURNER (Sussex, University, Brighton, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. Research supported by SERC, Rolls-Royce PLC, and GEC-Ruston Gas Turbine PLC. refs
(ASME PAPER 87-GT-72)

Experimental results for a modeled gas turbine rotor-stator system using both preswirled blade coolant and radially outward flowing disc coolant are presented. Although the preswirled coolant flow is found to have little effect on the pressure distribution below the preswirl nozzles, it is shown that considerable contamination of the preswirled coolant by the frictionally heated disc coolant can occur. A clear pressure inversion effect was found when coolant was provided by the preswirl nozzles alone, while the pressure under the rim seal increased with increasing rotational speed. Blade coolant flow increases the sealing flow requirement, except at the lowest flow rates. R.R.

A88-11017#
PREDICTION OF TURBULENT SOURCE FLOW BETWEEN COROTATING DISKS WITH AN ANISOTROPIC TWO-EQUATION TURBULENCE MODEL
SIAMACK A. SHIRAZI and C. RANDALL TRUMAN (New Mexico, University, Albuquerque) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. Research supported by Sandia National Laboratories and University of New Mexico. refs
(ASME PAPER 87-GT-73)

An anisotropic form of a low-Reynolds-number two-equation turbulence model has been implemented in a numerical solution for incompressible turbulent flow between corotating parallel disks. Transport equations for turbulent kinetic energy and dissipation rate were solved simultaneously with the governing equations for the mean-flow variables. Comparisons with earlier mixing-length predictions and with measurements are presented. Good agreement between the present predictions and the measurements of velocity components and turbulent kinetic energy was obtained. The low-Reynolds-number two-equation model was found to adequately model the near-wall region as well as the effects of rotation and streamline divergence which required ad hoc assumptions in the mixing-length model. Author

A88-11018#
NUMERICAL PREDICTION OF TURBULENT FLOW IN ROTATING CAVITIES
A. P. MORSE (Sussex, University, Brighton, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 13 p. refs
(ASME PAPER 87-GT-74)

Predictions of the isothermal, incompressible flow in the cavity formed between two corotating plane discs and a peripheral shroud have been obtained using an elliptic calculation procedure and a low-turbulence Reynolds number k-epsilon model for the estimation of turbulent transport. Both radial inflow and outflow are investigated for a wide range of flow conditions involving rotational Reynolds number up to one million. Although predictive accuracy is generally good, the computed flow in the Ekman layers for radial outflow often displays a retarded spreading rate and a tendency to laminarize under conditions which are known from experiment to produce turbulent flow. Author

A88-11019#
DEVELOPMENT OF CERAMIC HOT SECTION COMPONENTS FOR AGT 100 GAS TURBINE
D. A. TURNER and R. L. HOLTMAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p.
(ASME PAPER 87-GT-79)

The development of the AGT 100 gasifier turbine components in structural ceramic materials is described. Development is defined as the complete and iterative cycle from design, analysis, test, and design refinement culminating in successful demonstration of the design requirements. The components are analyzed by a linear elastic probabilistic approach, which involves finite element simulation of the component combined with a Weibull characterization of the brittle ceramic material strength distribution, to calculate a probability of survival for the component in the operating environment. Component test failure investigation has resulted in design modifications, and an improvement in component reliability has been demonstrated. Author

A88-11033*# Texas A&M Univ., College Station.
EFFECT OF RIB ANGLE ON LOCAL HEAT/MASS TRANSFER DISTRIBUTION IN A TWO-PASS RIB-ROUGHENED CHANNEL
P. R. CHANDRA, J. C. HAN, and S. C. LAU (Texas A & M University, College Station) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 9 p. refs
(Contract NAS3-24227)
(ASME PAPER 87-GT-94)

The naphthalene sublimation technique is used to investigate the heat transfer characteristics of turbulent air flow in a two-pass channel. A test section that resembles the internal cooling passages of gas turbine airfoils is employed. The local Sherwood numbers on the ribbed walls were found to be 1.5-6.5 times those for a fully developed flow in a smooth square duct. Depending on the rib angle-of-attack and the Reynolds number, the average ribbed-wall Sherwood numbers were 2.5-3.5 times higher than the fully developed values. R.R.

A88-11034#
PROCEDURES FOR DETERMINING SURFACE HEAT FLUX USING THIN FILM GAUGES ON A COATED METAL MODEL IN A TRANSIENT TEST FACILITY
J. E. DOORLY (Oxford University, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. Research supported by Rolls-Royce, PLC and Royal Aircraft Establishment. refs
(ASME PAPER 87-GT-95)

The paper describes how thin film surface heat flux gauges may be used to measure surface heat transfer rate to enamel-coated metal turbine blades. Flexible methods, which are also computationally efficient, for obtaining the heat transfer rate are described. Experimental results using the new coated metal turbine blades and processing techniques in a stationary transient cascade facility are given and are shown to agree well with results using the existing method for gauges on single-layer substrate blades. The application of the gauges for measuring highly unsteady heat transfer is also discussed. Author

A88-11037#
A QUALITATIVE METHOD FOR DETERMINING THE TEMPERATURE PATTERN OF RUN GAS TURBINE BLADES
G. MCQUIGGAN and W. LINKERT (Westinghouse Canada, Inc., Turbine and Generator Div., Hamilton) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 5 p. refs
(ASME PAPER 87-GT-102)

The paper proposes a quick and inexpensive qualitative method for determining the temperature pattern of run gas turbine blades (made from IN738 superalloy) that operate in the region of 815 C to 900 C. The method is based on measuring magnetism that develops in normally nonmagnetic materials upon exposure to high

temperatures. The magnetism induced in these alloys is thought to be the result of changes in the crystal lattice caused by operation of the alloy in a corrosive environment at elevated temperature. The development of a quantitative relationship might not be possible because of the interactive effects of temperature, environment, and time. I.S.

A88-11040#
THERMODYNAMICS AND PERFORMANCE PROJECTIONS FOR INTERCOOLED/REHEAT/RECUPERATED GAS TURBINE SYSTEMS
MAHER A. EL-MASRI (MIT, Cambridge, MA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-108)

Two methods for improving the performance of intercooled/recuperated (ICR) systems are assessed. Reheat ICR (RICR) cycles are compared with nonreheat ICR cycles for conservative and advanced components. The ICR cycles are for two-shaft engines and the RICR for two- and three-shaft engines. It is observed that for both conservative and advanced turbine component constraints without thermal barrier coating, the RICR cycle exceeds the ICR cycle by only 0.3 points and 6 percent in specific output. Whether reheat is preferable to a simple cycle turbine inlet temperature (TIT) depends on the form of the temperature difference and the additional loss induced by the reheat itself, and the feasibility of applying reheat depends on the constraints and design tradeoffs. Cooling flow rates as a function of TIT for ICR and RICR cycles and the use of water injection to improve ICR cycle performance are examined. I.F.

A88-11041#
EFFECTS OF CHANNEL ASPECT RATIO ON HEAT TRANSFER IN RECTANGULAR PASSAGE SHARP 180-DEG TURNS
C. S. FAN and D. E. METZGER (Arizona State University, Tempe) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-113)

Measured Nusselt numbers are presented for forced convection within and around sharp 180-deg turns in smooth channels of rectangular cross section. The turn geometry is characterized by channel height, inlet and outlet channel widths, and clearance at the tip of the turn. Twenty-seven different geometry parameter combinations were tested in the present study, extending previous work to two additional values of channel height and providing an assessment of the independent effect of channel aspect ratio for a wide variety of combinations of the other geometry parameters. Separately determined top wall, bottom wall, and side wall Nusselt numbers are presented individually along with azimuthal averages. In general, increasing channel aspect ratio results in smaller azimuthal heat transfer variations and increased overall channel heat transfer. Author

A88-11054#
COMPUTER PREDICTIONS OF EROSION DAMAGE IN GAS TURBINES
ABDEL AZIM A. F. EL-SAYED (Zagazig University, Egypt) and A. BROWN (Royal Military College of Science, Shrivenham, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-127)

In this article an iterative procedure is presented for estimating erosion in axial gas turbine blades. The procedure is applied to a two stage turbine and the erosion is estimated for a 12,000 hour engine running time. The effect of the erosion on engine performance is estimated through changes in pressure coefficient distribution around a blade section. Author

A88-11055#
A MODEL TO DETERMINE THE BEHAVIOUR OF A PRESSURE MEASUREMENT EQUIPMENT DURING NON-STATIC OPERATIONS OF GASTURBINE ENGINES
K.-U. LEMMER and J. HASS (Hamburg, Universitaet der Bundeswehr, Federal Republic of Germany) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. refs
(ASME PAPER 87-GT-128)

A mathematical model was developed to describe the behavior of a pressure measurement equipment of gas-turbine engines during nonstatic operations. The model determines the influence of the components of the measuring chain: a pressure measuring transducer, a hose pipe, and a pressure probe. It performs back calculations from the measured pressure signals to the real measuring value. The model was verified by pressure measurements with a calibrating device. The pressure measurements during the transition between different operating points of a gas-turbine engine and the adjustment of these pressure values with the help of the measuring-chain model are described. I.S.

A88-11068#
SPRAY PERFORMANCE OF A HYBRID INJECTOR UNDER VARYING AIR DENSITY CONDITIONS
A. K. JASUJA (Cranfield Institute of Technology, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. Research sponsored by the Royal Aircraft Establishment. refs
(ASME PAPER 87-GT-155)

The atomization characteristics of a fuel-air mixture preparation cum placement device featuring a conventional dual-orifice pressure atomizer spraying into a narrow diameter, airstream carrying tube are outlined in this paper. The experimental tests were carried out on gas oil over a range of ambient air pressures. A well established laser light-scattering technique was employed for dropsize measurements. The spray quality data collected in the present investigation allows some interesting comparisons against conventional airblast and pressure atomized spray data. Author

A88-11082#
APPLIED RELIABILITY/MAINTAINABILITY METHODOLOGY AS A FUNCTION WITHIN LIFE CYCLE COST
C. L. CALLIS and C. E. CURRY (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. refs
(ASME PAPER 87-GT-172)

This paper demonstrates application of reliability and maintainability (R&M) factors to determine supportability of aircraft turbine engines. R&M factors are expressed as operating and support parameters consistent with those required for LCC analysis as well as operating support level determinations. Author

A88-11083*# *Ford Motor Co., Dearborn, Mich.*
DEVELOPMENT OF THE AGT101 REGENERATOR SEALS
C. A. FUCINARI, J. K. VALLANCE, and C. J. RAHNKE (Ford Motor Co., Dearborn, MI) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. DOE-supported research.
(Contract DEN3-167)
(ASME PAPER 87-GT-173)

The design and development of the regenerator seals used in the AGT101 gas turbine engine are described in this paper. The all ceramic AGT101 gas turbine engine was designed for 100 hp at 5:1 pressure ratio with 2500F(1371C) turbine inlet temperature. Six distinct phases of seal design were investigated experimentally and analytically to develop the final design. Static and dynamic test rig results obtained during the seal development program are presented. In addition, analytical techniques are described. The program objectives of reduced seal leakage, without additional diaphragm cooling, to 3.6 percent of total engine airflow and higher

seal operating temperature resulting from the 2000F (1093C) inlet exhaust gas temperature were met. Author

A88-11092#
LABYRINTH SEAL FLOW MEASUREMENT BY TRACER GAS INJECTION
WILLIAM F. MCGREEHAN, FRED G. HAASER, and LAURENCE T. SHERWOOD (General Electric Co., Cincinnati, OH) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. Research supported by the General Electric Co. refs
(ASME PAPER 87-GT-187)

A practical system for flow measurement in rotating seals using the injection and sampling of a tracer gas is presented. Carbon dioxide or helium is injected as a tracer into a labyrinth seal at a controlled rate and gas samples are extracted downstream for concentration measurement. Test results from a rotating labyrinth seal rig were obtained over a range of seal pressure ratios and rotor speeds in order to determine the conditions which assure optimum tracer gas mixing. Seal leakage rates calculated by tracer gas concentration are compared to venturi flow measurements. Author

A88-11100#
FILM COOLING OF A TURBINE BLADE WITH INJECTION THROUGH TWO ROWS OF HOLES IN THE NEAR-ENDWALL REGION
R. J. GOLDSTEIN and P. H. CHEN (Minnesota, University, Minneapolis) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 7 p. USAF-supported research. refs
(ASME PAPER 87-GT-196; ASME PAPER 87-GT-196)

Measurements of film cooling on a simulated turbine blade are conducted using a mass transfer technique. Under the influence of the endwall, dramatic changes of film cooling performance occur on the convex surface of the blade as compared to the region where the flow is two-dimensional. The result is a triangular region, where coolant is swept away from the surface by the three dimensional vortex driven flow present between adjacent blades. In order to predict the area of this unprotected region, the influences of several parameters including density ratio, blowing rate and number of rows of injection holes are studied. The presence of the endwall affects the film cooling performance on the concave surface only slightly. Author

A88-11102#
HEAT TRANSFER TO ARRAYS OF IMPINGING JETS IN A CROSSFLOW
B. R. HOLLWORTH (Clarkson University, Potsdam, NY) and G. H. COLE (Idaho National Engineering Laboratories, Idaho Falls) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 9 p. refs
(ASME PAPER 87-GT-198)

Convective heat transfer measurements for staggered arrays of round turbulent air jets impinging upon a heated flat surface were obtained in the mean jet Reynolds number range of 2500-25,000. Streamwise variations in spanwise-averaged heat transfer were found using microfoil heat flux sensors, and heat transfer profiles were found to be periodic, with a peak corresponding to each spanwise row of holes. Peaks were displaced in the streamwise direction by the crossflow, with the largest deflections being exhibited by those nearest the exhaust end of the channel. Array-averaged heat transfer coefficients obtained by numerically averaging the local measurements were found to agree well with previous results. R.R.

A88-11109#
COMPARISON OF PREDICTED AND MEASURED VELOCITIES IN A COMPRESSOR DISK DRUM MODEL
D. G. ALBERGA, G. E. STEPHENS (Pratt and Whitney, East Hartford, CT), and B. V. JOHNSON (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 6 p. Research supported by Pratt and Whitney. refs
(ASME PAPER 87-GT-208)

LDV measurements of tangential velocity distributions in the bleed and the trapped cavities of an 11-cavity compressor drum model were obtained at disk tangential Reynolds numbers of about 2 x 10 to the 6th and compared with predicted values. Experimental results show the tangential velocity profiles in the bleed cavity to vary from near-solid-body at low flow rates to near-free-vortex at the highest flow rates. A decrease in tangential velocity strength in the trapped flow cavities with distance from the bleed cavity was also noted. The flow in the bleed and trapped cavities were modeled using an analysis coupling the flow in a core region with the flow in the disk boundary layers. The analytical model is shown to accurately predict the tangential velocity distribution, and hence the pressure drop, for a range of flow conditions and cavity locations. R.R.

A88-11112#
APPLICATION OF THE TRANSIENT TEST TECHNIQUE TO MEASURE LOCAL HEAT TRANSFER COEFFICIENTS ASSOCIATED WITH AUGMENTED AIRFOIL COOLING PASSAGES
H. J. SAABAS, S. C. ARORA, and W. ABDEL MESSEH (Pratt and Whitney Canada, Longueuil) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 10 p. refs
(ASME PAPER 87-GT-212)

Assumptions made in the application of a transient technique using active surface coatings for the determination of Nusselt number distributions within augmented passages typical of gas turbine airfoils are examined. An improved data reduction procedure and an alternative method for error analysis are proposed. It is found that for augmented surfaces, the one-dimensional conduction assumption made in the heat transfer solution is not valid for all times. It is also noted that the experimentally obtained quantities cannot be treated as values that are randomly distributed about some true value for all experimentally measured quantities. R.R.

A88-11114#
DEVELOPMENT AND APPLICATION OF A HIGH FREQUENCY WEDGE PROBE
H. BUBECK (Stuttgart, Universitaet, Federal Republic of Germany) and J. WACHTER ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. DFG-supported research. refs
(ASME PAPER 87-GT-216)

To investigate the three dimensional unsteady flow behind rotating blade rows of turbomachines, a high response pressure probe has been developed. Surface mounted miniature pressure transducers are used to measure the flow fluctuations, while the mean pressures are measured simultaneously with adjacent conventional pressure lead tubes. The steady state and the dynamic behavior of the probe were investigated. The application of the probe to the rotor exit flow of an axial compressor is described and results are presented. Author

A88-11116#
NEUTRON AND POSITRON TECHNIQUES FOR FLUID TRANSFER SYSTEM ANALYSIS AND REMOTE TEMPERATURE AND STRESS MEASUREMENT
P. A. E. STEWART (Rolls-Royce, PLC, Advanced Projects Dept., Bristol, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 15 p. Research supported by the Ministry of Defence (Procurement Executive).
(ASME PAPER 87-GT-219)

Present and projected applications of penetrating radiation techniques to gas turbine research and development are considered. Approaches discussed include the visualization and measurement of metal component movement using high energy X-rays, the measurement of metal temperatures using epithermal neutrons, the measurement of metal stresses using thermal neutron diffraction, and the visualization and measurement of oil and fuel systems using either cold neutron radiography or emitting isotope tomography. By selecting the radiation appropriate to the problem, the desired data can be probed for and obtained through imaging or signal acquisition, and the necessary information can then be extracted with digital image processing or knowledge based image manipulation and pattern recognition. R.R.

A88-11117#
EFFECT OF FLUID INERTIA ON THE PERFORMANCE OF SQUEEZE FILM DAMPER SUPPORTED ROTORS
L. A. SAN ANDRES and JOHN M. VANCE (Texas A & M University, College Station) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 12 p. refs
(ASME PAPER 87-GT-220)

The effect of fluid inertia on the synchronous steady-state operation of a centrally preloaded single mass flexible rotor supported in squeeze film bearing dampers is examined theoretically. For a model representative of some aircraft engine applications, frequency response curves are presented exhibiting the effect of fluid inertia on rotor excursion amplitudes and imbalance transmissibilities for both pressurized and unpressurized short open ended squeeze film damper supports. It is shown that a significant reduction in amplitude response and transmitted force is possible for dampers operating at moderately large squeeze film Reynolds numbers. Furthermore, for unpressurized dampers the possibilities of bi-stable operation and jump phenomena are shown to be reduced and virtually disappear at sufficiently large operating Reynolds numbers. Author

A88-11120#
A STUDY OF THE EFFECTS OF THERMAL BARRIER COATING SURFACE ROUGHNESS ON THE BOUNDARY LAYER CHARACTERISTICS OF GAS-TURBINE AEROFOILS
R. M. WATT, J. L. ALLEN (Oxford University, England), N. C. BAINES (Imperial College of Science and Technology, London, England), J. P. SIMONS, and M. GEORGE (Rolls-Royce, PLC, Bristol, England) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. SERC-supported research. refs
(ASME PAPER 87-GT-223)

The effect of thermal barrier coating surface roughness on the aerodynamic performance of gas-turbine aerofoils has been investigated for the case of a profile typical of current first-stage nozzle guide vane design. Cascade tests indicate a potential for significant extra loss, depending on Reynolds number, due to thermal barrier coating in its 'as-sprayed' state. In this situation polishing coated vanes is shown to be largely effective in restoring their performance. The measurements also suggest a critical low Reynolds number below which the range of roughness tested has no effect on cascade efficiency. Transition detection involved a novel use of thin-film anemometers painted and fired onto the TBC surfaces. Author

A88-11142#
PARTICLE TRANSPORT ACROSS THE TRANSPIRED TURBULENT BOUNDARY LAYER
HAMDI KOZLU and JEAN F. LOUIS (MIT, Cambridge, MA) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 11 p. refs
(Contract DE-AC21-83MC-20334)
(ASME PAPER 87-GT-265)

Wind tunnel data and theoretical results are used to study the effects of surface inclination and density of particulates on deposition control by transpiration, with application to the control of deposition of small particles contributing most of the mass of the solid carryover entering turbines burning coal-derived fuel. The effects of size and injection rates on deposition are considered, and the interaction between transpiration and the inertial impaction of particles is investigated using glass particles. Turbulent Schmidt numbers obtained from tests conducted on an inclined plate with coal particles in order to determine the density effects on the particle concentration profiles were in agreement with the predictions of Tchen (1974) for the flat plate. R.R.

A88-11439#
AN OPTIMAL CONTROL METHOD FOR PASSAGE OF A FLEXIBLE ROTOR THROUGH RESONANCES
Z. VIDERMAN and I. PORAT (Technion - Israel Institute of Technology, Haifa) ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control (ISSN 0022-0434), vol. 109, Sept. 1987, p. 216-223. refs

This paper deals, by means of modal analysis, with the effects of control forces on passage through resonances of a flexible rotor. Several control methods are evaluated, and the necessary number of dampers and their optimal location are determined. A fundamental interpretation is offered for the problem as a whole. Author

A88-11585#
NDE AT TWELVE O'CLOCK HIGH
BERNHARD R. TITTMANN (Rockwell International Science Center, Thousand Oaks, CA) Mechanical Engineering (ISSN 0025-6501), vol. 109, Sept. 1987, p. 72-74.

The role of NDE in the evaluation of materials, in particular materials for aircraft components, is examined. Computer-based ultrasonic systems and real-time radiography are applicable for analyzing material properties. The development of NDE methods, such as fiber-optic borescopes, and X-ray, dye-penetrant, and magnetic techniques for testing difficult to reach places (welds) is being researched. The need for laser-based ultrasonic techniques for in-process and in-service control and monitoring of materials is discussed. Consideration is given to noncontacting acoustooptical process monitoring and the use of heat sources, such as laser beams, to generate thermal waves on the surface of materials. I.F.

A88-11825#
FORCE COMMUTATED DIRECT FREQUENCY CHANGERS FOR AEROSPACE POWER APPLICATIONS
Y. KIM and M. EHSANI (Texas A & M University, College Station) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 325-330. refs

This paper describes a new VSCF system whose prime power source is a permanent magnet generator. The terminal voltage of permanent magnet generator is not controllable since the excitation is constant and the output frequency varies proportionally to the engine speed. Forced turn-off frequency changers are employed as the interface between permanent magnet generator and constant frequency supply. Control laws of the VSCF system, which reduce power ratings of the system and increase efficiency in the VSCF, are established. Finally, microprocessor-based control techniques, which provide the input power factor control as well as voltage and frequency control, are described. Author

A88-12294#
SIMILARITY OF EJECTOR WALL-PRESSURE DISTRIBUTIONS
M. S. CHANDRASEKHARA, A. KROTHAPALLI (Florida State University, Tallahassee), and D. BAGANOFF (Stanford University, CA) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1266-1268.
(Contract F49620-79-C-0189)

The wall static pressure distribution of a multiple, underexpanded jet ejector of the kind employed in thrust augmentation is presently found to scale well with average throat static pressures. This effect is ascribed to the absence of the well-defined acoustic interaction that is generally observed in the single underexpanded jet. The self-similarity obtained only holds, however, for short nozzle-to-throat distances; at greater distances, a clear breakdown is noted. O.C.

A88-12657
OPTICAL SYSTEMS FOR GAS TURBINE ENGINES
MARK WRIGLEY (Negretti Aviation, Croydon, England) IN: Contemporary optical instrument design, fabrication, and testing; Proceedings of the Meeting, Innsbruck, Austria, Apr. 17, 18, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 231-237.

The design and fabrication of a turbine-blade pyrometer transducer for in situ measurements of blade temperature in operating gas-turbine engines are described and illustrated with diagrams, drawings, graphs, and photographs. Consideration is given to the primary components (optical probe, fiber-optic cable, and electronics), the operating environment (extreme temperatures and pressures, vibration, EMI, and liquids), the design specifications, and specific fabrication techniques. It is pointed out that electrooptic transducers of this type reduce the measurement error to + or - 10 C, and that the same sensors can be used to measure blade-tip clearance and shaft speed or to detect flame-out. T.K.

A88-12697
SELF-ADJUSTING FLIGHT ELECTRONICS (SAFE)
THOMAS P. CAUDELL (Hughes Artificial Intelligence Center, Calabasas, CA) and I. DAVID LEVY (Hughes Aircraft Co., Electro-Optical and Data Systems Group, El Segundo, CA) IN: Infrared detectors, sensors, and focal plane arrays; Proceedings of the Meeting, San Diego, CA, Aug. 21, 22, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 145-150. USAF-supported research.

The design and performance of SAFExpert, an expert-system program developed (as part of the SAFE program) to adjust the clock levels and biases of avionic CCD detector arrays, are described. The basic adjustment problem is defined; the expert-system approach (combining basic knowledge of the device physics and engineering experience) is explained; and the process flow and operation of SAFExpert are presented in diagrams and characterized in detail. In test optimizations involving three different CCD arrays preset to three different sets of (degraded-performance) clock/bias levels, SAFExpert achieved 50-percent better bucket capacity in about 8 min than a human expert obtained (by manual tweaking) in 30-60 min. The applicability of SAFExpert to other parameter-adjustment and optimization problems is discussed. T.K.

A88-12725* Missouri Univ., Columbia.
DEVELOPMENT AND IMPLEMENTATION OF AN AERODYNAMIC HOLOGRAPHIC INTERFEROMETRY SYSTEM
JOHN B. MILES (Missouri-Columbia, University, Columbia), STEPHEN E. DUNAGAN, and JAMES L. BROWN (NASA, Ames Research Center, Moffett Field, CA) IN: High speed photography, videography, and photonics IV; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 186-198. refs

An aerodynamic holographic interferometry system has been developed and adapted for use with an existing supersonic wind tunnel. The basis for the system is briefly discussed, and the flow investigation for which the system was developed is outlined. The system is described, including detailed equipment schematics and cost figures. Some details and guidance are given with regard to experience in reducing the interferometry fringe data via the Abel transformation to obtain density fields and, in turn, velocity fields. Finally, representative results are shown together with complementary laser velocimetry measurements and Navier-Stokes computations. C.D.

A88-12732
VIDEO DATA LINK PROVIDES TELEVISION PICTURES IN NEAR REAL TIME VIA TACTICAL RADIO AND SATELLITE CHANNELS
RICHARD V. HARTMAN (Singer Co., Dalmo Victor Div., Belmont, CA) IN: Airborne reconnaissance X; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 21-25.

Advances in sophisticated algorithms and parallel VLSI processing have resulted in the capability for near real-time transmission of television pictures (optical and FLIR) via existing telephone lines, tactical radios, and military satellite channels. Concepts have been field-demonstrated with production-ready engineering development models using transform compression techniques. Preliminary design has been completed for packaging an existing command post version into a 20-pound enclosure for use on jeeps, backpacks, RPVs, helicopters, and reconnaissance aircraft. The system will also have a built-in error correction code unit, allowing operation via communciations media exhibiting a bit error rate of 0.01 or better. Author

A88-12838* Aerospace Corp., Los Angeles, Calif.
TEST OF IR ARRAYS ON THE KUIPER AIRBORNE OBSERVATORY
R. W. RUSSELL, G. S. ROSSANO, D. K. LYNCH, G. T. COLON-BONET, J. A. HACKWELL (Aerospace Corp., Space Sciences Laboratory, Los Angeles, CA) et al. IN: Infrared technology XII; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 88-98.
(Contract NAS2-12155)

NASA's Kuiper Airborne Observatory, which is a C-141 transport aircraft equipped with a 90-cm, all-reflective altazimuth telescope, has been engaged in the Kuiper Infrared Technology Experiment. Attention is presently given to the Experiment's flight series for state-of-the-art two-dimensional, 500-element arrays that use either blocked impurity band or bulk silicon devices. The switched FET readout scheme used on the three arrays flown thus far yields exceptionally low crosstalk. System sensitivities are found to be sufficient for the detection of both pointlike and extended sources; several of each type have been used in staring and scanning experiments. O.C.

A88-12840
AN UNCOOLED LINESCAN THERMAL IMAGER FOR GROUND AND AIRBORNE USE
T. J. LIDDICOAT, M. V. MANSI (Plessey Research Roke Manor, Ltd., England), D. E. BURGESS, and P. A. MANNING (Royal Signals and Radar Establishment, Malvern, England) IN: Infrared technology XII; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 108-114. Research supported by the Ministry of Defence and Plessey Research and Technology, Ltd.

An account is given of the design features and performance capabilities of pyroelectric IR sensors employing 64-element linear detector arrays, germanium lenses, and a chopper for the modulation of the incoming radiation. In one of the two systems presented, the peak value of the signal is read from the detector with the chopper in 'open' position and displayed in the form of a grey-scale picture; in the second system, the difference between the signals obtained with the chopper in 'open' and 'closed' positions is determined and displayed as a grey-scaled image. The sensors may be used in a panned mode to give large-area surveillance, as well as in a staring mode to furnish image

information in virtue of the motion of the target. They may also be used in an aircraft-mounted linescan mode. O.C.

A88-12843
A COMPACT HIGH PERFORMANCE THERMAL IMAGER
A. H. LETTINGTON (Royal Signals and Radar Establishment, Malvern, England) and W. T. MOORE (Rank Pullin Controls, Ltd., Laughton, England) IN: Infrared technology XII; Proceedings of the Meeting, San Diego, CA, Aug. 19, 20, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 146-151.

A compact, low-cost, high-performance thermal imager based on a novel coaxial scanning technique is presented. Design requirements for this imager configuration encompass the avoidance of vignetting and pupil wander in the scanning elements and objective lenses, as well as the maximization of detector cold shielding. The requirements are met by the use of SPRITE IR detectors, and the use of coincident pupils (as in the coaxial scanner). Attention is given to representative military applications for the thermal imager, including RPVs, airborne pods, helicopters, and land-based sights. O.C.

A88-12903
THIN-FILM TEMPERATURE SENSORS DEPOSITED BY RADIO FREQUENCY CATHODIC SPUTTERING
J. C. GODEFROY, C. GAGEANT, D. FRANCOIS, and M. PORTAT (ONERA, Chatillon-sous-Bagneux, France) Journal of Vacuum Science and Technology A (ISSN 0734-2101), vol. 5, Sept.-Oct. 1987, p. 2917-2923. DRET-supported research. refs

In order to gain better knowledge of the heat exchanges occurring in aircraft turbines, ONERA is presently developing thin-film heat sensors capable of operating up to a maximum temperature of 1100 C. These high-temperature sensors are surface thermometers and fluxmeters of the gradient type. They consist of metal films forming thermocouples and insulating films such as alumina or zircon stabilized by yttrium oxide. These layers are deposited by RF cathodic sputtering on substrates such as IN100, DS200, and CMSX2 superalloys which are either aluminized or coated with an NiCoCrAlY alloy. The present state of development of the thermometers is described as well as the first results obtained. Author

A88-12949
ELASTIC BUCKLING OF INTERNALLY PRESSURIZED CYLINDER-BULKHEAD COMBINATIONS
G. D. GALLETLY and J. BLACHUT (Liverpool, University, England) Institution of Mechanical Engineers, Proceedings, Part C - Mechanical Engineering Science (ISSN 0263-7154), vol. 201, no. C4, 1987, p. 259-262. refs

Unstiffened spherical caps attached to unstiffened cylindrical shells by means of circumferential stiffening rings are considered. The loading is by uniform internal pressure, and the object of the analysis is to determine if elastic bifurcation buckling can occur, and, if so, where the buckles will be located. The BOSOR 5 shell buckling program was used in the analysis, and several stiffener geometries were investigated. Results show that elastic buckling can occur in the cylindrical portion of some cylinder-bulkhead combinations. If the structure is subjected to repeated loading, then the formation and disappearance of the elastic buckles could contribute to the initiation of fatigue cracks. Some of the geometries investigated are like some commercial aircraft configurations. Author

A88-13083#
STRESS INTENSITY FACTORS AND RESIDUAL STRENGTH OF A CRACKED STIFFENED PANEL
ATSUHIRO SASAKI and KOICHI HIRAOKA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 618-625. In Japanese. refs

An analytical method for determining the stress intensity factors and residual strength of a cracked stiffened panel for the next-generation commercial transport aircraft is presented. Crack verification for the panel is carried out using a modification of Poe's method, and calculations are made of stress-strain, fastener flexibility, stress intensity factors, stringer load factor, and residual strength of the cracked panel. S.H.

A88-13084#
STRUCTURE SIMPLIFICATION AROUND A CUTOUT - APPLICATION OF A SIMPLIFIED DAMAGE TOLERANCE DESIGN CHART
TETSUO UCHIMOTO, KANYA KOGA, and KOICHI HIRAOKA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 394, 1986, p. 626-632. In Japanese. refs

The paper describes the development of a simplified damage tolerance design chart for the simplified structure around the cutout for the next-generation commercial transport aircraft. The buildup structure, outer panel, and frame seal are integrated to form the simplified structure, and a damage tolerance evaluation method is established and compared with other methods. An analytical method for determining the stress intensity factor for cracks is discussed. S.H.

N88-10209# National Bureau of Standards, Gaithersburg, Md. Center for Fire Research.
TEST RESULTS AND PREDICTIONS FOR THE RESPONSE OF NEAR-CEILING SPRINKLER LINKS IN A FULL-SCALE COMPARTMENT FIRE
LEONARD Y. COOPER and DAVID W. STROUP Sep. 1987 45 p
(NBSIR-87-3633) Avail: NTIS HC A03/MF A01

Data acquired during a test program which involved full-scale, sprinklered, compartment fires is presented and analyzed. This work focuses attention specifically on key features of the typical sprinkler link deployment/response problem. It is found that the elevated temperature, upper smoke layer which develops inevitably in compartment fires can have a major impact on the thermal response of sprinkler links. It is shown that traditionally accepted methods of predicting sprinkler response which do not account for this upper layer can be totally inadequate. Link response predictions used here involve a new method of calculation which does take account of the smoke layer environment. Favorable comparisons between predictions and experiment are obtained and experiments for further validation of this method are recommended. Finally, it is found that sprinkler link-to-ceiling spacing can have a significant effect on the thermal response of links and it is recommended that a method which accounts for this effect be developed and validated. Author

N88-10231 Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (West Germany).
DETECTION OF TARGETS IN THE PRESENCE OF CLUTTER USING TARGET ECHO MODULATIONS CAUSED BY ROTATING STRUCTURES Thesis - Hochschule der Bundeswehr, Neubiberg, West Germany
G. RETZER Nov. 1986 142 p In GERMAN; ENGLISH summary
(Contract BMVG-T/RF31/71455/71340)
(REPT-12-86; LFD-256; ETN-87-90393) Avail: Issuing Activity

The radar detection of hovering helicopters in the presence of clutter was investigated. It is shown that radar backscatter modulation by helicopter rotors can be described as line spectra in the frequency domain, with the spacings equivalent to the product of the rotor rotation frequency and the number of rotor blades. Typical values are between 10 and 40 Hz. Experimental results obtained with a coherent E-band pulse Doppler radar are in good agreement with calculated values. Based on these results, a detector which allows the detection of hovering helicopters in the presence of clutter is proposed. The required radar parameters, such as radar dwell time and radar pulse repetition frequency, are discussed. ESA

N88-10278# European Space Agency, Paris (France).
EXPERIENCE ABOUT THE APPLICATION AND VALUATION OF ROUGHNESS STRIPS FOR BOUNDARY LAYER TRANSITION CONTROL IN WIND TUNNEL TESTS IN THE HIGH-SPEED RANGE
SIEGHARD TUSCHE Mar. 1987 93 p Transl. into ENGLISH of Erfahrungen ueber die Anwendung und Beurteilung von Rauhigkeitsstreifen zur Beeinflussung des Grenzschichtumschlags bei Windkanalversuchen im Hochgeschwindigkeitsbereich (Goetingen, Fed. Republic of Germany, DFVLR) 1986 Original language document announced as N87-14291
(ESA-TT-1028; DFVLR-MITT-86-12; ETN-87-90664) Avail: NTIS HC A05/MF A01; original report in German available from DFVLR, Cologne, West Germany DM 56

Placing and application of artificial transition strips for aerodynamic tests are described. Methods used in high-speed wind tunnels for checking the effectiveness of transition strips are given. ESA

N88-10283# National Aerospace Lab., Amsterdam (Netherlands). Fluid Dynamics Div.
MEASUREMENT TECHNIQUES IN LOW-SPEED TURBULENT FLOWS: A REPORT ON EUROMECH 202
B. VANDERBERG and A. BERTELRUD 5 Jun. 1986 17 p Presented at the EUROMECH 202 Colloquium, Marknesse, The Netherlands, 7-10 Oct. 1985
(NLR-MP-86038-U; B8701065; ETN-87-90828) Avail: NTIS HC A03/MF A01

Measurement techniques in low speed turbulent flows and typical swept wings were discussed. Wakes were included. ESA

N88-10305# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Abteilung fuer Turbinen und Schaufelkuehlung.
COMPARISON OF DIFFERENT KINDS OF COMPACT CROSS FLOW HEAT EXCHANGERS
WERNER SIEMENS Sep. 1986 82 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1076)
(DFVLR-FB-86-63; ISSN-0171-1342; ETN-87-90448) Avail: NTIS HC A05/MF A01; DFVLR, Cologne, West Germany

A computer program for the calculation of compact heat exchangers for gas turbines was developed. The most important coefficients, pressure drops, and effectiveness of different kinds of exchangers were calculated as a function of Mach number, the dimensions of the exchanger, and the compactness. From the aerothermodynamic point of view, the plate exchanger is best, closely followed by the lancet heat exchanger. The ribs of the plate version have no significant effect on the characteristics, but are required for stiffness and uniform channel height. The tube heat exchanger can only compete as far as the transferable heat is concerned. ESA

N88-10338 British Petroleum Co. Ltd., London (England).
STEERING MECHANISM Patent Application
JOHN KIMBERLY WELLS, inventor 21 May 1986 12 p Filed 10 Oct. 1985 Priority 17 Oct. 1984 GB 8426278
(EP-PATENT-0-181-700-A1; EP-PATENT-APPL-SN-85307273.4; INT-PATENT-CLASS-B62D-1/18; ETN-87-98641) Avail: UK Patent Office, 25 Southampton Buildings, London WC2A 1A4, United Kingdom

A collapsible steering mechanism for a vehicle, comprising a steering shaft having a steering means connected to its upper end and a steering gear connected to its lower end is presented. The steering shaft comprises an elongated energy absorbing tube having a bond between the tube and one or both of the steering gear and the steering means. The longitudinal axial component of the bond is adapted to disrupt under crash impact and to allow the tube to progressively collapse and absorb the impact energy. ESA

N88-10339*# General Electric Co., Lynn, Mass. Aircraft Engine Business Group.
THE DESIGN OF A TURBOSHAFT SPEED GOVERNOR USING MODERN CONTROL TECHNIQUES Final Report, 30 Sep. 1982 - 20 Feb. 1985
G. DELOSREYES and D. R. GOUCHOE Feb. 1986 220 p
(Contract NAS3-22763)
(NASA-CR-175046; NAS 1.26:175046) Avail: NTIS HC A10/MF A01 CSCL 13I

The objectives of this program were: to verify the model of off schedule compressor variable geometry in the T700 turboshaft engine nonlinear model; to evaluate the use of the pseudo-random binary noise (PRBN) technique for obtaining engine frequency response data; and to design a high performance power turbine speed governor using modern control methods. Reduction of T700 engine test data generated at NASA-Lewis indicated that the off schedule variable geometry effects were accurate as modeled. Analysis also showed that the PRBN technique combined with the maximum likelihood model identification method produced a Bode frequency response that was as accurate as the response obtained from standard sinewave testing methods. The frequency response verified the accuracy of linear models consisting of engine partial derivatives and used for design. A power turbine governor was designed using the Linear Quadratic Regulator (LQR) method of full state feedback control. A Kalman filter observer was used to estimate helicopter main rotor blade velocity. Compared to the baseline T700 power turbine speed governor, the LQR governor reduced droop up to 25 percent for a 490 shaft horsepower transient in 0.1 sec simulating a wind gust, and up to 85 percent for a 700 shaft horsepower transient in 0.5 sec simulating a large collective pitch angle transient. Author

N88-10377# British Aerospace Aircraft Group, Woodford (England). Structures Dept.
THE FATIGUE PROPERTIES OF AEROSPACE STEELS UNDER CONSTANT AMPLITUDE AND FLIGHT-BY-FLIGHT SIMULATED LOADING Final Report
J. A. FORSYTH Feb. 1986 34 p
(Contract MOD-A93B/1548)
(BAE-MSM-R-GEN-0566; BR99378; ETN-87-90679) Avail: NTIS HC A03/MF A01

Fatigue tests were carried out to evaluate the fatigue properties of alloy steels S99, S155 and AF1410, which span a wide range in toughness value (50 to 150 MPa square root m). The fighter aircraft loading sequence (FALSTAFF) and conventional constant amplitude loading were used for the fatigue tests. The expected tensile strength levels (specification minima) are met by the alloys S99 and S155. The AF1410 material is slightly below specification. The fatigue performance of S155 is significantly inferior to that of S99 and AF1410. ESA

N88-10386# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
CRITERIA FOR DETERMINATION OF SIGNIFICANT LOAD CYCLES IN VARIABLE AMPLITUDE LOAD SEQUENCES
A. U. DEKONING and G. LIEFTING 1 Mar. 1986 41 p Presented at the International Symposium on Fatigue Crack Closure, Charleston, W.Va., May 1986
(Contract NIVR-1823/01702-N)
(NLR-MP-86013-U; B8701061; ETN-87-90824) Avail: NTIS HC A03/MF A01

The crack opening behavior of a fatigue crack in a centrally cracked panel was studied using a discretized version of the Dugdale and Barenblatt model. The effect of crack growth was included. Results for constant amplitude loading agree with the literature. The effect of single overload-underload combinations and of simple block loading programs on the crack opening behavior was analyzed. The results were compared with predictions based on an empirical model (CORPUS). The criteria used in the CORPUS model to select significant load excursions in the applied load sequence were checked. Both models were used to predict crack growth under a simplified landing gear load sequence. The

predicted crack opening loads and the crack growth lives agree with experiment. ESA

N88-11002# Hoechst CeramTec A.G., Selb (West Germany).
DEVELOPMENT OF A STATISTICALLY PROVEN INJECTION MOLDING METHOD FOR REACTION BONDED SILICON NITRIDE, SINTERING REACTION BONDED SILICON NITRIDE, AND SINTERED SILICON NITRIDE Final Report, 1 Jul. 1985 - 30 Jun. 1986
MATTHIAS STEINER 1987 49 p In GERMAN; ENGLISH summary Sponsored by the Bundesministerium fuer Forschung und Technologie, Federal Rep. of Germany
(ETN-87-90575) Avail: NTIS HC A03/MF A01

A statistically proven, series injection molding technique for ceramic components was developed for the construction of engines and gas turbines. The flow behavior of silicon injection-molding materials was characterized and improved. Hot-isostatic-pressing reaction bonded silicon nitride (HIPRBSN) was developed. A nondestructive component evaluation method was developed. An injection molding line for HIPRBSN engine components precombustion chamber, flame spreader, and valve guide was developed. This line allows the production of small series for engine tests. ESA

N88-11003# Rolls-Royce Ltd., Derby (England).
INVESTMENT FOUNDRY MELTING STOCK. ROLLS ROYCE REQUIREMENTS AND DEMANDS IN TERMS OF QUALITY AND THE RELATIONSHIP TO END PRODUCT PERFORMANCE
A. K. GIBBONS 28 Apr. 1987 5 p Submitted for publication
(PNR90397; ETN-87-91000) Avail: NTIS HC A02/MF A01

Requirements and controls in terms of melt stock production procedures, quality, and acceptance for gas turbine investment castings are discussed. The influence of melt stock quality on the castings produced is reviewed. ESA

N88-11048# Tennessee Univ., Knoxville. Dept. of Electrical Engineering.
PROCESS SUPPORT COMPRESSOR MOTOR ELECTROMAGNETIC DESIGN SUMMARY
J. M. BAILEY Mar. 1987 31 p
(Contract DE-AC05-84OT-21400)
(DE87-014359; K/SUB-85-03528/2) Avail: NTIS HC A03/MF A01

A 30-hp, 15,000-rpm, permanent magnet motor has been designed and is now being built. The direct drive motor has 72 slots and eight poles. Using A. O. Smith Magnetic, a flux plot was obtained and the flux density throughout one pole pitch has been determined. The poles are connected in a four-pole series, parallel WYE. Each pole requires 30 A for a total per phase current of 60 A. The torque capability is 2638 oz-in. DOE

N88-11080# Rolls–Royce Ltd., Derby (England).
BOUNDARY LAYER PROFILE INVESTIGATIONS DOWNSTREAM OF AN AERO–ENGINE INTAKE ANTI–ICING AIR EXHAUST SLOT
S. J. DOWNS and E. H. JAMES (Loughborough Univ. of Technology, England) 31 May 1987 8 p Presented at the 32nd ASME International Gas Turbine Conference and Exhibition, Anaheim, Calif., 31 May - 4 Jun. 1987
(PNR90378; ETN-87-90994) Avail: NTIS HC A02/MF A01

The boundary layer profile downstream of the anti-icing air exhaust slot of a two-dimensional aeroengine inlet section was investigated by a pitot rake. Results for a range of inlet engine airflows with and without exhaust anti-icing air introduced are presented. The boundary layer is found to be turbulent as expected owing to the presence upstream in the wind tunnel of a fixed water spray grid which may be used to simulate engine operation in clouds. Injection of anti-icing air produces a sublayer downstream of the anti-icing air exhaust plane. Three methods of deriving boundary layer thickness from the experimental data were used and theoretical values determined. Experimental measurements confirm theoretical trends. ESA

N88-11081# Rolls-Royce Ltd., Derby (England). Advanced Research Lab.
OPTICAL FLOW DIAGNOSTIC MEASUREMENTS IN TURBOMACHINERY
D. G. JONES and R. J. PARKER 1 Jun. 1987 13 p Presented at the 8th ISABE Conference, Cincinnati, Ohio, 15-19 Jun. 1987 Previously announced in IAA as A87-46245 Sponsored by the United Kingdom Ministry of Defense Procurement Executive
(PNR90396; ETN-87-90999) Avail: NTIS HC A03/MF A01

Flow measurements within the passages of rotating model fans was measured using laser holographic flow visualization and laser transit anemometry. The complementary nature of the two techniques uses the ability of holography to provide a diagnostic identification in three dimensions of main features of the flow and the ability of laser anemometry to provide quantitative measurements of the flow velocity at selected spatial locations. It is shown how the optical techniques, when suitably designed and ruggedized for a hostile environment, provide quantitative information of the intrapassage flows for a sequence of tests on wide chord fan blades, which aided the validation of their design intent. ESA

N88-11088*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
IMPACT OF TURBULENCE MODELING ON NUMERICAL ACCURACY AND EFFICIENCY OF COMPRESSIBLE FLOW SIMULATIONS
THOMAS J. COAKLEY Sep. 1986 9 p
(NASA-TM-88333; A-86326; NAS 1.15:88333) Avail: NTIS HC A02/MF A01 CSCL 20D

Discussed is the numerical implementation of turbulence models used in viscous compressible flow simulations and their performance described with respect to numerical accuracy, efficiency and stability. The basic approach utilizes the Reynolds-averaged compressible Navier-Stokes equations in which the Reynolds stresses and heat fluxes are mathematically modeled by suitable turbulence models. The turbulence models investigated include zero-, one-, and two-equation eddy viscosity models. The flow fields investigated include theoretical and supersonic flows about two-dimensional and axisymmetric bodies. Discussions concerning the numerical implementation of models include differencing procedures and boundary conditions used to assume numerical stability and accuracy. Numerical performance is also evaluated by comparing computations with experimental results. Author

N88-11089*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
COMPUTATION OF TRANSONIC SEPARATED WING FLOWS USING AN EULER/NAVIER-STOKES ZONAL APPROACH
UENVER KAYNAK, TERRY L. HOLST, and BRIAN J. CANTWELL (Stanford Univ., Calif.) Jul. 1986 152 p
(NASA-TM-88311; A-86271; NAS 1.15:88311) Avail: NTIS HC A08/MF A01 CSCL 20D

A computer program called Transonic Navier Stokes (TNS) has been developed which solves the Euler/Navier-Stokes equations around wings using a zonal grid approach. In the present zonal scheme, the physical domain of interest is divided into several subdomains called zones and the governing equations are solved interactively. The advantages of the Zonal Grid approach are as follows: (1) the grid for any subdomain can be generated easily; (2) grids can be, in a sense, adapted to the solution; (3) different equation sets can be used in different zones; and, (4) this approach allows for a convenient data base organization scheme. Using this code, separated flows on a NACA 0012 section wing and on the NASA Ames WING C have been computed. First, the effects of turbulence and artificial dissipation models incorporated into the code are assessed by comparing the TNS results with other CFD codes and experiments. Then a series of flow cases is described where data are available. The computed results, including cases with shock-induced separation, are in good agreement with experimental data. Finally, some futuristic cases are presented to

demonstrate the abilities of the code for massively separated cases which do not have experimental data. Author

N88-11101*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A 1987 PROGRESS REPORT OF MANUFACTURING TECHNIQUES FOR GRAVITY PROBE B GYROSCOPE ROTORS
ROY A. TAYLOR, ED WHITE, and WILLIAM J. REED Sep. 1987 32 p
(NASA-TM-100312; NAS 1.15:100312) Avail: NTIS HC A03/MF A01 CSCL 14B

The significant improvements in the manufacture of Gravity Probe B gyroscope rotors developed since the publication of the last report on this project are presented. The improvements include the polishing machine structure, rough laps, finishing/polishing laps, lapping procedure, measurement techniques, and a summary of the manufacturing status. These six areas represent significant improvements in the manufacture of the gyroscope rotors to meet flight requirements. Author

N88-11133# Rolls-Royce Ltd., Derby (England).
TRANSMISSION EFFICIENCY IN ADVANCED AEROSPACE POWERPLANT
J. A. DOMINY 2 Feb. 1987 14 p Presented at the ASME/SAE/AIAA Joint Propulsion Conference, San Diego, Calif., 29 Jun. - 2 Jul. 1987
(PNR90391; TER662; TIA165189; ETN-87-90996) Avail: NTIS HC A03/MF A01

For aerospace powerplant requiring high power reduction gearboxes, an analytical method of estimating the efficiency of candidate transmissions was developed. The analysis was calibrated against an existing transmission and applied to gearboxes for single and contrarotating propfans and larger ultra-high-bypass ratio engines. In all cases the predicted efficiencies are broadly acceptable. The single most powerful influence is the gearbox configuration which is generally imposed by airframe requirements. ESA

N88-11134# Rolls-Royce Ltd., Derby (England).
THE USE OF KEVLAR ON AERO-ENGINE FAN CONTAINMENT CASINGS
I. F. STEWART 18 May 1987 9 p Presented at the Impact 87 Conference, Bremen, Federal Rep. of Germany, 18-22 May 1987
(PNR90410; ETN-87-91003) Avail: NTIS HC A02/MF A01

The use of Kevlar to reduce the weight of fan containment casings is described. Continuous layers of dry, woven Kevlar are wrapped around a light former (the casing). Upon release, the blade punctures the casing and its energy is absorbed by the whole circumference of Kevlar, unlike a traditional metal casing which has to be thick enough so that all the blade energy is absorbed in the local area of impact where the blade hits the casing. Tests indicate that casing weights 50% of ARMVO casings are achievable. A theoretical model for predicting Kevlar deflections was developed. Over a wide range of blade energies, weave types, wrapping tensions, and numbers of layers it gives good agreement with test results. The significant reduction in deflections predicted for increased wrapping tension agrees well with measured test results. ESA

N88-11135*# Timken Co., Canton, Ohio.
IMPROVED OIL-OFF SURVIVABILITY OF TAPERED ROLLER BEARINGS Final Report, 1982 - 1987
GARY E. KREIDER and PETER W. LEE Oct. 1987 86 p
(Contract NAS3-23689; DA PROJ. 1L1-61102-AH-45)
(NASA-CR-180804; NAS 1.26:180804; AVSCOM-TR-87-C-29)
Avail: NTIS HC A05/MF A01 CSCL 13I

The aim of this program is to improve the oil-off survivability of a tapered roller bearing when applied to a helicopter transmission, since the tapered bearing has shown a performance advantage in this application. However, the critical roller end-rib conjunction is vulnerable to damage in an oil-off condition. Three powdered metal materials were selected to use as the rib material for oil-off evaluation. These were: M2 steel to a 65% density, CBS 1000M 65% density, and CBS 1000M 75% density. The bearing styles tested were ribbed cone (inner race) and ribbed cup (outer race). Carburized solid CBS 600 was also used as a ribbed material for comparison of oil-off results. The tests were conducted at six speeds from 4000 rpm (0.26 million DN) through 37000 rpm (2.4 million DN).The ribbed cup style bearing achieved longer lives than the ribbed cone style. A standard bearing lasted only 10 minutes at 4000 rpm; however, the 30-min oil-off goal was achieved through 11000 rpm using the survivable ribbed cup bearing. The oil-off lives at 37000 rpm were less than 10 seconds. The grinding of the powder metal materials and surface preparation to achieve an open porosity is extremely critical to the oil-off performance of the powder metal component. Author

N88-11139# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
RELIABILITY OF FINITE ELEMENT METHODS IN NORTH AMERICA
JERZY J. KACPRZYNSKI Jul. 1987 25 p
(AGARD-R-748) Avail: NTIS HC A03/MF A01

The reliability of finite element analysis techniques in place of structural test are discussed in the context of airworthiness assessment. Using an example as illustration, it is shown that in order to obtain meaningful results, the analysis must be performed with extreme care by an experienced analyst. The reliance on the finite element analysis alone may result in serious misdiagnosis. The verification and the certification of programs and the certification of users are discussed. Some of the most important tests for validation of finite element programs are presented. Author

N88-11140*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
TURBINE ENGINE HOT SECTION TECHNOLOGY, 1985
Oct. 1985 443 p Conference held in Cleveland, Ohio, 22-23 Oct. 1985
(NASA-CP-2405; E-2727; NAS 1.55:2405) Avail: NTIS HC A19/MF A01 CSCL 20K

The Turbine Engine Section Technology (HOST) Project Office of the Lewis Research Center sponsored a workshop to discuss current research pertinent to turbine engine hot section durability problems. Presentations were made concerning hot section environment and the behavior of combustion liners, turbine blades, and turbine vanes.

N88-11142*# United Technologies Research Center, East Hartford, Conn.
THE DEVELOPMENT OF A HIGH TEMPERATURE STATIC STRAIN GAGE SYSTEM
CHARLES O. HULSE, RICHARD S. BAILEY, and HOWARD P. GRANT (Pratt and Whitney Aircraft, East Hartford, Conn.) *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 45-49 Oct. 1985
(Contract NAS3-23722)
Avail: NTIS HC A19/MF A01 CSCL 14B

The objective of this program is to develop electrical resistance strain gages which will permit the measurement of static strains on nickel and cobalt superalloy parts inside gas turbine engines running on a test stand. The specific goal is to develop a complete system able to make strain measurements up to plus or minus 2000 mu strain with a total error of no more than plus or minus 10 percent over a 50 hour period at 1250 K. The initial part of this work consisted of a strain gage alloy development effort in which a variety of alloys were evaluated after being prepared by drop-casting or splat cooling. Author

N88-11143*# Pratt and Whitney Aircraft, East Hartford, Conn.
DEVELOPMENT OF HEAT FLUX SENSORS FOR TURBINE AIRFOILS
WILLIAM H. ATKINSON, MARCIA A. CYR, and RICHARD R. STRANGE *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 51-58 Oct. 1985
(Contract NAS3-23529)
Avail: NTIS HC A19/MF A01 CSCL 14B

The objectives of this program are to develop heat flux sensors suitable for installation in hot section airfoils of advanced aircraft turbine engines and to experimentally verify the operation of these heat flux sensors in a cylinder in a cross flow experiment. Embedded thermocouple and Gardon gauge sensors were developed and fabricated into both blades and vanes. These were then calibrated using a quartz lamp bank heat source and finally subjected to thermal cycle and thermal soak testing. These sensors were also fabricated into cylindrical test pieces and tested in a burner exhaust to verify heat flux measurements produced by these sensors. The results of the cylinder in cross flow tests are given. Author

N88-11146*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE LEWIS STRAIN GAUGE LABORATORY: STATUS AND PLANS
HOWARD F. HOBART and HERBERT A. WILL *In its* Turbine Engine Hot Section Technology, 1985 p 77-79 Oct. 1985
Avail: NTIS HC A19/MF A01 CSCL 14B

An in-house lab was established for developing, testing, and evaluating high-temperature strain gauges and to aid in in-house applications of high-temperature strain instrumentation. The lab is automated to provide computer control of oven temperatures, imposed strain, and data sampling. Author

N88-11150*# United Technologies Research Center, East Hartford, Conn.
FUEL-INJECTOR/AIR-SWIRL CHARACTERIZATION
J. B. MCVEY, J. B. KENNEDY, and J. C. BENNETT (Connecticut Univ., Storrs.) *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 109-117 Oct. 1985
(Contract NAS3-24352)
Avail: NTIS HC A19/MF A01 CSCL 20D

The objectives of this program are to establish an experimental data base documenting the behavior of gas turbine engine fuel injector sprays as the spray interacts with the swirling gas flow existing in the combustor dome, and to conduct an assessment of the validity of current analytical techniques for predicting fuel spray behavior. Emphasis is placed on the acquisition of data using injector/swirler components which closely resemble components currently in use in advanced aircraft gas turbine engines, conducting tests under conditions that closely simulate or closely approximate those developed in actual combustors, and conducting a well-controlled experimental effort which will comprise using a combination of low-risk experiments and experiments requiring the use of state-of-the-art diagnostic instrumentation. Analysis of the data is to be conducted using an existing, TEACH-type code which employs a stochastic analysis of the motion of the dispersed phase in the turbulent continuum flow field. Author

N88-11153*# Garrett Turbine Engine Co., Phoenix, Ariz.
DILUTION JET MIXING PROGRAM, PHASE 3
R. SRINIVASAN, G. MYERS, and C. WHITE *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 127-132 Oct. 1985
(Contract NAS3-22110)
Avail: NTIS HC A19/MF A01 CSCL 20D

The objectives of the program were: (1) to extend the data base on mixing of a single-sided row of jets with a confined crossflow, (2) to collect a data base on mixing of multiple rows of jets with confined crossflow, (3) to develop empirical jet mixing correlations, and (4) to perform limited three-dimensional calculations for some of these test configurations. The tests were performed with uniform mainstream conditions for several orifice plate configurations. Schematics of the test section and the orifice configurations are given. Temperature and pressure measurements were made in the test section at 4 axial and 11 transverse stations, using a 60-element rake probe. The measured temperature distributions for these tests are reported. Author

N88-11154*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ON THE MIXING OF A ROW OF JETS WITH A CONFINED CROSSFLOW
J. D. HOLDEMAN *In its* Turbine Engine Hot Section Technology, 1985 p 133-138 Oct. 1985
Avail: NTIS HC A19/MF A01 CSCL 20D

Mean temperature profiles calculated with an interactive microcomputer code which evaluates dilution-zone design alternatives are presented to show the effects of flow and geometric variables on the mixing of a single row of jets injected through sharp-edged orifices into a uniform flow of a different temperature in a constant area duct. In addition, this program is used to calculate profiles for opposed rows of jets with their centerlines in-line, by assuming that the confining effect of an opposite wall is equivalent to that of a plane of symmetry between opposed jets. Author

N88-11160*# Pratt and Whitney Aircraft, East Hartford, Conn.
COOLANT PASSAGE HEAT TRANSFER WITH ROTATION
T. J. HAJEK and A. W. HIGGINS *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 187-201 Oct. 1985
(Contract NAS3-23691)
Avail: NTIS HC A19/MF A01 CSCL 20D

The objective is to develop a heat transfer and pressure drop data base, computational fluid dynamic techniques, and correlations for multi-pass rotating coolant passages with and without flow turbulators. The experimental effort is focused on the simulation of configurations and conditions expected in the blades of advanced aircraft high pressure turbines. With the use of this data base, the effects of Coriolis and buoyancy forces on the coolant side flow can be included in the design of turbine blades. Author

N88-11161*# Stanford Univ., Calif. Thermosciences Div.
HEAT TRANSFER WITH VERY HIGH FREE STREAM TURBULENCE
ROBERT J. MOFFAT and PAUL K. MACIEJEWSKI *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 203-215 Oct. 1985
(Contract NAG3-522)
Avail: NTIS HC A19/MF A01 CSCL 20D

Stanton numbers as much as 350 percent above the accepted correlations for flat plate turbulent boundary layer heat transfer have been found in experiments on a low velocity air flow with very high turbulence (up to 50 percent). These effects are far larger that have been previously reported and the data do not correlate as well in boundary layer coordinates (Stanton number and Reynolds number) as they do in simpler coordinates: h vs. X. The very high relative turbulence levels were achieved by placing the test plate in different positions in the margin of a large diameter free jet. The large increases may be due to organized structures of large scale which are present in the marginal flowfield around a free jet. Author

N88-11162*# Minnesota Univ., Minneapolis.
PREDICTION OF TURBINE BLADE HEAT TRANSFER
SUHAS V. PATANKAR *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 217-219 Oct. 1985
(Contract NAG3-579)
Avail: NTIS HC A19/MF A01 CSCL 20D

It is planned to incorporate a number of low Reynolds number turbulence models in a general two-dimensional boundary layer calculation procedure. This will be applied to different flow conditions over turbine blades and the predictions will be compared with experimental data. The prediction activity will lead to a

recommendation about a satisfactory turbulence model for turbine blade heat transfer. Author

N88-11163*# Scientific Research Associates, Inc., Glastonbury, Conn.
FLOW IN A MODEL TURBINE STATOR
R. C. BUGGEIN, S. J. SHAMROTH, and W. R. BRILEY *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 221-226 Oct. 1985
(Contract NAS3-24358)
Avail: NTIS HC A19/MF A01 CSCL 20D

In view of the complex nature of the flowfield in the hot section of gas turbine engines, the need to predict heat transfer and flow losses, the possible appearance of separation and strong secondary flows, etc., the present effort is focusing upon a Navier-Stokes approach to the three dimensional turbine stator problem. The advantages of a full Navier-Stokes approach are clear since when combined with a suitable turbulence model these equations represent the flow and heat transfer physics. In particular, the Navier-Stokes equations accurately represent possible separated regions and regions of significant secondary flow. In addition, the Navier-Stokes approach allows representation of the entire flow field by a single set of equations, thus avoiding problems associated with representing different regions of the flow by different equations and then matching flow regions. Author

N88-11164*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
3D INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS
L. T. DAME, P. C. CHEN, M. S. HARTLE, and H. T. HUANG *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 227-237 Oct. 1985
(Contract NAS3-23698)
Avail: NTIS HC A19/MF A01 CSCL 20K

The objective is to develop analytical tools capable of economically evaluating the cyclic time dependent plasticity which occurs in hot section engine components in areas of strain concentration resulting from the combination of both mechanical and thermal stresses. Three models were developed. A simple model performs time dependent inelastic analysis using the power law creep equation. The second model is the classical model of Professors Walter Haisler and David Allen of Texas A and M University. The third model is the unified model of Bodner, Partom, et al. All models were customized for linear variation of loads and temperatures with all material properties and constitutive models being temperature dependent. Author

N88-11170*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
HIGH TEMPERATURE STRESS-STRAIN ANALYSIS
ROBERT L. THOMPSON *In its* Turbine Engine Hot Section Technology, 1985 p 287-301 Oct. 1985
Avail: NTIS HC A19/MF A01 CSCL 20K

The objectives of the high temperature structures program are threefold: to assist in the development of analytical tools needed to improve design analysis and procedures for the efficient and accurate prediction of the nonlinear structural response of hot-section components; to aid in the calibration, validation, and evaluation of the analytical tools by comparing predictions with experimental data; and to evaluate existing as well as advanced temperature and strain measurement instrumentation. Author

N88-11171*# Southwest Research Inst., San Antonio, Tex.
CONSTITUTIVE MODELING FOR ISOTROPIC MATERIALS
ULRIC S. LINDHOLM *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 303-306 Oct. 1985
(Contract NAS3-23925)
Avail: NTIS HC A19/MF A01 CSCL 20K

The objective is to develop a unified constitutive model for finite element structural analysis of turbine engine hot-section components. This effort constitutes a different approach for non-linear finite-element computer codes which have heretofore been based on classical inelastic methods. The unified constitutive theory to be developed will avoid the simplifying assumptions of classical theory and should more accurately represent the behavior of superalloy materials under cyclic loading conditions and high temperature environments. During the first two years of the program, extensive experimental correlations were made with two representative unified models. The experiments were both uniaxial and biaxial at temperatures up to 1093 C (2000 F). In addition, the unified models were adopted to the MARC finite element code and used for stress analysis of notched bar and turbine blade geometries. Author

N88-11172*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
CONSTITUTIVE MODELING FOR ISOTROPIC MATERIALS
V. G. RAMASWAMY, R. H. VANSTONE, L. T. DAME, and J. H. LAFLEN *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 307-320 Oct. 1985
(Contract NAS3-23927)
Avail: NTIS HC A19/MF A01 CSCL 20K

Constitutive theories were evaluated against a large uniaxial and multiaxial data base that was generated as part of this work. The experimental approach was to determine the constitutive behavior of Rene 80 under a multitude of conditions that are important in the design of gas turbine blades and vanes. The experimental and analytical goals of this program were successfully accomplished. A new multiaxial constitutive model which can represent the complex nonlinear high temperature behavior of Rene 80 was developed. The model was extensively verified on data at several temperatures. Author

N88-11173*# Pratt and Whitney Aircraft, East Hartford, Conn.
CREEP FATIGUE LIFE PREDICTION FOR ENGINE HOT SECTION MATERIALS (ISOTROPIC): THIRD YEAR PROGRESS REVIEW
RICHARD S. NELSON and JOHN F. SCHOENDORF *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 321-327 Oct. 1985
(Contract NAS3-23288)
Avail: NTIS HC A19/MF A01 CSCL 20K

This program is designed to investigate fundamental damage processes, identify modeling strategies, and develop practical models which can be used to guide the early design and development of new engines and to increase the durability of existing engines. A review is given of the base program, completed in 1984, which included the comparison and evaluation of several popular high-temperature life prediction approaches as applied to continuously cycled isothermal specimen tests. The option program, of which one year is completed, is designed to develop models which can account for complex cycles and loadings, such as thermomechanical cycling, cumulative damage, multiaxial stress/strain rates, and environmental effects. Author

N88-11174*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
ELEVATED TEMPERATURE CRACK GROWTH
S. N. MALIK, R. H. VANSTONE, K. S. KIM, and J. H. LAFLEN *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 329-340 Oct. 1985
(Contract NAS3-23940)
Avail: NTIS HC A19/MF A01 CSCL 20K

The purpose is to determine the ability of currently available P-I integrals to correlate fatigue crack propagation under conditions that simulate the turbojet engine combustor liner environment. The utility of advanced fracture mechanics measurements will also be evaluated during the course of the program. To date, an appropriate specimen design, a crack displacement measurement method, and boundary condition simulation in the computational model of the specimen were achieved. Alloy 718 was selected as an analog material based on its ability to simulate high temperature behavior at lower temperatures. Tensile and cyclic tests were run at several strain rates so that an appropriate constitutive model could be developed. Suitable P-I integrals were programmed into a finite

element post-processor for eventual comparison with experimental data. Author

N88-11175*# Pratt and Whitney Aircraft, East Hartford, Conn.
LIFE PREDICTION AND CONSTITUTIVE MODELS FOR ENGINE HOT SECTION ANISOTROPIC MATERIALS PROGRAM
G. A. SWANSON *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 341-349 Oct. 1985
(Contract NAS3-23939)
Avail: NTIS HC A19/MF A01 CSCL 20K

The purpose is to develop life prediction models for coated anisotropic materials used in gas temperature airfoils. Two single crystal alloys and two coatings are now being tested. These include PWA 1480; Alloy 185; overlay coating, PWA 286; and aluminide coating, PWA 273. Constitutive models are also being developed for these materials to predict the plastic and creep strain histories of the materials in the lab tests and for actual design conditions. This nonlinear material behavior is particularly important for high temperature gas turbine applications and is basic to any life prediction system. Author

N88-11182*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THERMAL EXPANSION MISMATCH AND OXIDATION IN THERMAL BARRIER COATINGS
G. C. CHANG, W. PHUCHAROEN (Cleveland State Univ., Ohio.), and R. A. MILLER *In its* Turbine Engine Hot Section Technology, 1985 p 405-425 Oct. 1985
(Contract NCC3-27)
Avail: NTIS HC A19/MF A01 CSCL 13I

Thermal barrier coatings (TBC) for advanced gas turbine blades have been under intensive development during the last several years. This investigation is intended to achieve a clearer understanding of the mechanical behavior of plasma sprayed zirconia-yttria TBCs, involving a nickle-chromium-aluminum bond coat. The near term objectives are to study the stress states in a relatively simple model TBC subjected to steady state thermal loading. The resulting thermal expansion mismatch and oxidation have been primary targets for the study. The finite element approach and the effects of thermal mismatch and oxidation are described. A proposed mechanism for oxidation induced coating failure is also presented. Author

N88-11183*# Garrett Turbine Engine Co., Phoenix, Ariz.
THERMAL BARRIER COATING LIFE PREDICTION MODEL DEVELOPMENT
T. E. STRANGMAN, J. F. NEUMANN, and A. TASOOJI *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 427-432 Oct. 1985
Avail: NTIS HC A19/MF A01 CSCL 13I

This program focuses on predicting the lives of two types of strain-tolerant and oxidation-resistant thermal barrier coating (TBC) systems that are produced by commercial coating suppliers to the gas turbine industry. The plasma-sprayed TBC system is composed of a low pressure, plasma sprayed applied, oxidation resistant NiCrAlY bond coating. The other system is an air plasma sprayed yttria (8 percent) partially stabilized zirconia insulative layer. Author

N88-11185*# Pratt and Whitney Aircraft, East Hartford, Conn.
THERMAL BARRIER COATING LIFE PREDICTION MODEL DEVELOPMENT
J. T. DEMASI and K. D. SHEFFLER *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 445-455 Oct. 1985
(Contract NAS3-23944)
Avail: NTIS HC A19/MF A01 CSCL 13I

The objective is to develop an integrated life prediction model accounting for all potential life-limiting thermal barrier coating (TBC) degradation and failure modes, including spallation resulting from cyclic thermal stress, oxidation degradation, hot corrosion, erosion and foreign object damage. Author

N88-11186*# Rensselaer Polytechnic Inst., Troy, N.Y.
COMPOSITE STRUCTURAL MATERIALS Annual Progress Report no. 50, 1 May 1986 - 30 Apr. 1987
ROBERT G. LOEWY and STEPHEN E. WIBERLEY Aug. 1987 93 p
(Contract NGL-33-018-003)
(NASA-CR-181416; NAS 1.26:181416) Avail: NTIS HC A05/MF A01 CSCL 20K

The development and application of composite materials to aerospace vehicle structures which began in the mid 1960's has now progressed to the point where what can be considered entire airframes are being designed and built using composites. Issues related to the fabrication of non-resin matrix composites and the micro, mezzo and macromechanics of thermoplastic and metal matrix composites are emphasized. Several research efforts are presented. They are entitled: (1) The effects of chemical vapor deposition and thermal treatments on the properties of pitch-based carbon fiber; (2) Inelastic deformation of metal matrix laminates; (3) Analysis of fatigue damage in fibrous MMC laminates; (4) Delamination fracture toughness in thermoplastic matrix composites; (5) Numerical investigation of the microhardness of composite fracture; and (6) General beam theory for composite structures. Author

N88-11198# Aeronautical Research Labs., Melbourne (Australia).
THE INFLUENCE OF LOAD CYCLE RECONSTITUTION ON FATIGUE BEHAVIOUR
J. M. FINNEY and F. G. HARRIS Aug. 1986 37 p
(ARL-STRUC-R-424; AR-004-498) Avail: NTIS HC A03/MF A01

Fatigue experiments have been conducted to assess the influence of the method of reconstituting a load sequence from a range-pair counted load spectrum for a fighter aircraft. In addition to the original flight-by-flight sequence, several quite-structured reconstituted sequences and random reconstituted sequences were used, all sequences having identical range-pair counts. There was little or no difference in crack propagation lives or total lives of two specimen geometries for the several structured sequences which were designed to give the extremes in crack growth life. There was, also, no significant difference in crack propagation lives for specimens tested under the flight-by-flight and random sequences. Crack growth under the more structured sequences was significantly slower than under the more fluctuating sequences (random and flight-by-flight), though the maximum difference of 1.59:1 is small relative to other uncertainties in fatigue life assessment. These results provide a basis for implementing the Aircraft Fatigue Data Analysis System which utilizes strain range-pair counting. Author

N88-11202*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AGARD STANDARD AEROELASTIC CONFIGURATIONS FOR DYNAMIC RESPONSE. CANDIDATE CONFIGURATION I.-WING 445.6
E. CARSON YATES, JR. Aug. 1987 78 p
(NASA-TM-100492; NAS 1.15:100492) Avail: NTIS HC A05/MF A01 CSCL 20K

To promote the evaluation of existing and emerging unsteady aerodynamic codes and methods for applying them to aeroelastic problems, especially for the transonic range, a limited number of aerodynamic configurations and experimental dynamic response data sets are to be designated by the AGARD Structures and Materials Panel as standards for comparison. This set is a sequel to that established several years ago for comparisons of calculated and measured aerodynamic pressures and forces. This report presents the information needed to perform flutter calculations for the first candidate standard configuration for dynamic response along with the related experimental flutter data. Author

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

N88-10463# Technische Univ., Brunswick (West Germany). Fakultaet fuer Maschinenbau und Elektrotechnik.
CONTRIBUTIONS TO THE MODELING OF WIND SHEAR FOR DANGER STUDIES Ph.D. Thesis [BEITRAEGE ZUR MODELLIERUNG VON SCHERWIND FUER GEFAEHRDUNGSUNTERSUCHUNGEN]
MANFRED SWOLINSKY 1986 202 p In GERMAN
(ETN-87-90442) Avail: NTIS HC A10/MF A01

Wind models for flight simulation and the study of the danger during landing due to wind shear were developed. It is demonstrated that the typical wind conditions in weather phenomena such as thunderstorm fall winds and surface boundary layer wind shear can be approximated by simple engineering models, whereby known solutions and flow forms from flow mechanics were adapted. The good agreement between models and airborne measurements is demonstrated. Based on the developed models the degree of danger during landing under different wind shear conditions was estimated. ESA

N88-10464# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Abteilung Wolkenphysik.
THE DEPENDENCE OF THE NORMALIZED ICE ACCRETION THICKNESS ON CLOUD-PHYSICAL PARAMETERS
HANS-EBERHARD HOFFMANN, ROLAND ROTH, and JOHANN DEMMEL Jan. 1987 64 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1080)
(DFVLR-FB-87-08; ISSN-0171-1342; ETN-87-90455) Avail: NTIS HC A04/MF A01; DFVLR, Cologne, West Germany DM 24.50

Normalized ice accretion thickness was studied using the measurement results of 38 icing research aircraft flights in icing clouds. Normalized ice accretion is the ice accretion thickness on 3 metal cylinders in flow direction, for a true air speed of 125 kt, and a flight path in clouds of 10 NM (i.e., 18.5 km). In the investigated range of liquid water content up to 0.50 g/cum, the normalized ice thickness grows linearly with increasing liquid water content; it is a little larger for cloud particles freezing instantaneously. The thickness is larger for smaller cylinder diameters. In the temperature range between minus 2 and minus 14 C, a difference in temperature has only a little influence, differences in particle phase and particle size distribution have no influence on the normalized ice accretion thickness. ESA

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LIFE SCIENCES

Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and planetary biology.

A88-10154* Psycho-Linguistic Research Associates, Menlo Park, Calif.
VERSATILE SIMULATION TESTBED FOR ROTORCRAFT SPEECH I/O SYSTEM DESIGN
CAROL A. SIMPSON (Psycho-Linguistic Research Associates, Menlo Park, CA) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 33-37. USAF-supported research.
(Contract NAS2-12425)
(SAE PAPER 861661)

A versatile simulation testbed for the design of a rotorcraft speech I/O system is described in detail. The testbed will be used to evaluate alternative implementations of synthesized speech displays and speech recognition controls for the next generation of Army helicopters including the LHX. The message delivery logic is discussed as well as the message structure, the speech recognizer command structure and features, feedback from the recognizer, and random access to controls via speech command. K.K.

A88-10158
AN INTEGRATED DISPLAY FOR VERTICAL SITUATION AWARENESS IN COMMERCIAL TRANSPORT AIRCRAFT
ROGER HOUCK, BRIAN D. KELLY, and JOHN WIEDEMANN (Boeing Commercial Airplane Co., Seattle, WA) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 61-64.
(SAE PAPER 861770)

The need for a sideview-presentation vertical situation display (VSD) for use in commercial transport aicraft is demonstrated. The preliminary conceptual VSD format includes an inside-out presentation with a moving scale and vertical map translating around a fixed airplane symbol. The information is scaled along altitude and distance axes to permit present, predicted, and future altitude requirements to be integrated with other relevant vertical situational information. It is believed that the completed VSD concept will improve the flightcrew's awareness of the aircraft's spatial position throughout the flight. K.K.

A88-10160* Boeing Commercial Airplane Co., Seattle, Wash.
COMPARISON OF PROGRAMMABLE LEGEND KEYBOARD AND DEDICATED KEYBOARD FOR CONTROL OF THE FLIGHT MANAGEMENT COMPUTER
JEAN M. CRANE, GEORGE P. BOUCEK, JR. (Boeing Commercial Airplane Co., Seattle, WA), and WAYNE D. SMITH (Boeing Military Airplane Co., Wichita, KS) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 83-90. refs
(Contract NAS1-17635)
(SAE PAPER 861772)

A study is described which compares two types of input devices used to operate a flight management computer: a programmable legend (multifunction) keyboard and a conventional (dedicated) keyboard. Pilot performance measures, subjective responses, and a timeline analysis were used in evaluating the two keyboard concepts. A discussion of the factors to be considered in the implementation of a multifunction keyboard is included. Author

A88-10162
THE ADVANTAGES OF A PRIMARY FLIGHT DISPLAY
J. E. HUTCHINSON (International Federation of Air Line Pilots Associations, Egham, England) IN: Aerospace Behavioral Engineering Technology Conference, 5th, Long Beach, CA, Oct. 13-16, 1986, Proceedings . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 101-104.
(SAE PAPER 861730)

The features of a primary flight display (PFD) are discussed as well as its advantages over conventional instrumentation. The present PFD is part of the electronic flight instrument system which is standard on the current series of Airbus models. Consideration is given to failure indications, the airspeed scale, the flight path vector (FPV), and the FPV with head-up display. K.K.

A88-12639* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
PERSPECTIVE TRAFFIC DISPLAY FORMAT AND AIRLINE PILOT TRAFFIC AVOIDANCE
STEPHEN R. ELLIS, MICHAEL W. MCGREEVY (NASA, Ames Research Center, Moffett Field; California, University, Berkeley), and ROBERT J. HITCHCOCK (San Jose State University, CA) Human Factors (ISSN 0018-7208), vol. 29, Aug. 1987, p. 371-382. refs
(Contract NCC2-86)

Part-task experiments have examined perspective projections of cockpit displays of traffic information as a means of presenting aircraft separation information to airline pilots. Ten airline pilots served as subjects in an experiment comparing the perspective projection with plan-view projections of the same air traffic situations. The pilots' task was to monitor the traffic display in order to decide if an avoidance maneuver was needed. Pilots took more time to select avoidance maneuvers with a conventional plan-view display than with an experimental perspective display. In contrast to previous results, if the pilots selected a maneuver with the perspective display, they were more likely to choose one with a vertical component. Tabulation of the outcomes of their initial avoidance decisions with both perspective and plan-view displays showed that they were more likely to achieve required separation with maneuvers chosen with the aid of perspective displays. Author

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MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A88-10929
THE ACCURACY-RELATED PARAMETRIC REDUCTION OF MATHEMATICAL MODELS [O TOCHNOSTNOI PARAMETRICHESKOI REDUKTSII MATEMATICHESKIKH MODELEI]
IGOR' EVGEN'EVICH EFIMOV (AN USSR, Institut Problem Modelirovaniia v Energetike, Kiev, Ukrainian SSR) Elektronnoe Modelirovanie (ISSN 0204-3572), vol. 9, July-Aug. 1987, p. 3-7, 89. In Russian. refs

The paper examines several approaches to the construction of algorithms for the simplification of mathematical models on the basis of accuracy-related parametric reduction. This reduction consists in a formalization of the coordination of the model structure and the accuracy indices of the model parameters. The results are of interest in connection with the analysis of aircraft flight dynamics. B.J.

A88-10965* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TRADITIONAL VERSUS RULE-BASED PROGRAMMING TECHNIQUES - APPLICATION TO THE CONTROL OF OPTIONAL FLIGHT INFORMATION
WENDELL R. RICKS and KATHY H. ABBOTT (NASA, Langley Research Center, Hampton, VA) SPIE, Technical Symposium Southeast on Optics, Electro-optics, and Sensors, Orlando, FL, May 17-22, 1987, Paper. 8 p. refs

A traditional programming technique for controlling the display of optional flight information in a civil transport cockpit is compared to a rule-based technique for the same function. This application required complex decision logic and a frequently modified rule base. The techniques are evaluated for execution efficiency and implementation ease; the criterion used to calculate the execution efficiency is the total number of steps required to isolate hypotheses that were true and the criteria used to evaluate the implementability are ease of modification and verification and explanation capability. It is observed that the traditional program is more efficient than the rule-based program; however, the rule-based programming technique is more applicable for improving programmer productivity. I.F.

A88-11115#
INITIAL USER EXPERIENCE WITH AN ARTIFICIAL INTELLIGENCE PROGRAM FOR THE PRELIMINARY DESIGN OF CENTRIFUGAL COMPRESSORS
CAROL J. RUSSO (General Electric Co., Aircraft Engine Business Group, Lynn, MA), DENNIS J. NICKLAUS, and SIU S. TONG (General Electric Co., Schenectady, NY) ASME, International Gas Turbine Conference and Exhibition, 32nd, Anaheim, CA, May 31-June 4, 1987. 8 p. refs
(ASME PAPER 87-GT-217)

An approach in which existing analysis codes are coupled to a generic AI framework, ENGINEOUS, is proposed for the evaluation of the design of turbomachinery components. Using a simple and incomplete rule base, ENGINEOUS is shown to quickly identify nonobvious solutions balanced for conflicting multiple goals in a small number of iterations which vary linearly with the number of variables. The solution path and driving logic are easily visible, and a parameter study option can rapidly evaluate potential design trade-offs, allowing a critique of the selected design to balance performance against development risks. R.R.

A88-11394
COMPUTING COMPLEX FOR A SYSTEM FOR THE RADIO-ACOUSTIC SOUNDING OF THE ATMOSPHERE - HARDWARE FACILITIES [VYCHISLITEL'NYI KOMPLEKS SISTEMY RADIOAKUSTICHESKOGO ZONDIROVANIIA ATMOSFERY.APPARATNYE SREDSTVA]
V. I. ALEKHIN, O. V. DRIAMOV, A. I. KLIUSHIN, I. V. KORYTTSEV, and G. I. SIDOROV Radiotekhnika (Kharkov) (ISSN 0485-8972), no. 76, 1986, p. 71-77. In Russian. refs

The paper describes the computing complex of a radio-acoustic sounding system which is used at airports to investigate the meteorological parameters of the atmospheric surface layer. This complex provides for the real-time input of period values of the Doppler frequency of the reflected signal, the calculation of meteorological-parameter values, and the printout of results. Particular attenion is given to the design and operation of the controllers. B.J.

A88-12526
AIAA COMPUTERS IN AEROSPACE CONFERENCE, 6TH, WAKEFIELD, MA, OCT. 7-9, 1987, TECHNICAL PAPERS
Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1987, 397 p. For individual items see A88-12527 to A88-12579.

Papers are presented on the analysis of Ada as a prototyping language; the evaluation of a dual processor implementation for a fault inferring nonlinear detection system; fault-tolerant systems; intelligent interfaces to aircraft systems; the implementation of a research prototype on a fault monitoring and diagnosis system;

future data acquisition capabilities; and the application of AI technology to the analysis and synthesis of reliable software systems. Topics discussed include the spaceplane's astronaut's associate; model-based health monitoring for reusable launch vehicles; Space Shuttle telemetry analysis by a real-time expert system; avionics, AI, and embedded processing systems; methodology requirements for intelligent systems architecture; and commonsense reasoning and superconductivity for self-replicating telerobots. Consideration is given to autonomous spacecraft operations; semiautonomous control for satellite servicing; and expert system control for airborne radar surveillance. I.F.

A88-12532*# Charles River Analytics, Inc., Cambridge, Mass.
EVALUATION OF A DUAL PROCESSOR IMPLEMENTATION FOR A FAULT INFERRING NONLINEAR DETECTION SYSTEM
P. M. GODIWALA, A. K. CAGLAYAN (Charles River Analytics, Inc., Cambridge, MA), and F. R. MORRELL (NASA, Langley Research Center, Hampton, VA) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 43-51. refs
(AIAA PAPER 87-2762)

The design of a modified fault inferring nonlinear detection system (FINDS) algorithm for a dual-processor configured flight computer is described. The algorithm was changed in order to divide it into its translational dynamics and rotational kinematics and to use it for parallel execution on the flight computer. The FINDS consists of: (1) a no-fail filter (NFF), (2) a set of test-of-mean detection tests, (3) a bank of first order filters to estimate failure levels in individual sensors, and (4) a decision function. NFF filter performance using flight recorded sensor data is analyzed using a filter autoinitialization routine. The failure detection and isolation capability of the partitioned algorithm is evaluated. A multirate implementation for the bias-free and bias filter gain and covariance matrices is discussed. I.F.

A88-12539*# Bolt, Beranek, and Newman, Inc., Cambridge, Mass.
INTELLIGENT INTERFACES TO AIRCRAFT SYSTEMS
ROBERT SCHUDY, KEVIN CORKER, and SHELDON BARON (BBN Laboratories, Inc., Cambridge, MA) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 93-99. refs
(Contract NAS1-17335)
(AIAA PAPER 87-2776)

An approach for developing intelligent aiding systems for airline flight crews is proposed. This approach proceeds in four cycles: (1) National Traffic Safety Board data and pilot interviews are used to determine the areas in which pilots require aid; (2) a pilot information processing model is designed; (3) an intelligent pilot-aiding model is developed; and (4) systems for implementing aiding functions are defined. This approach is utilized to design a general situation-response pilot-aiding system. The situation-response model and the structure of a general situation-response pilot-aiding system are described. The computer implementation of the situation-response information processing model is examined. I.F.

A88-12540*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
IMPLEMENTATION OF A RESEARCH PROTOTYPE ONBOARD FAULT MONITORING AND DIAGNOSIS SYSTEM
MICHAEL T. PALMER, KATHY H. ABBOTT, PAUL C. SCHUTTE, and WENDELL R. RICKS (NASA, Langley Research Center, Hampton, VA) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 100-107. refs
(AIAA PAPER 87-2777)

Due to the dynamic and complex nature of in-flight fault monitoring and diagnosis, a research effort was undertaken at NASA Langley Research Center to investigate the application of artificial intelligence techniques for improved situational awareness. Under this research effort, concepts were developed and a software architecture was designed to address the complexities of onboard monitoring and diagnosis. This paper describes the implementation of these concepts in a computer program called FaultFinder. The implementation of the monitoring, diagnosis, and interface functions as separate modules is discussed, as well as the blackboard designed for the communication of these modules. Some related issues concerning the future installation of FaultFinder in an aircraft are also discussed. Author

A88-12544#
AOSP - MULTIPROCESSOR ARCHITECTURE AND SYSTEM CONSIDERATIONS
DANIEL J. DECHANT and FRANK A. HORRIGAN (Raytheon Co., Sudbury, MA) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 129-135. refs
(Contract F30602-78-C-0027; F30602-80-C-0206; F3602-84-C-0094)
(AIAA PAPER 87-2790)

The architecture of the Advanced Onboard Signal Processor (AOSP), its embedded survivable local area network, its operating system software, and its fault tolerance characteristics are described. The application of the AOSP to a sensor signal processing system is examined. The partitioning of the application processing functions and the programming of the applications are discussed. I.F.

A88-12558#
AVIONICS, ARTIFICIAL INTELLIGENCE, AND EMBEDDED PROCESSING SYSTEMS
PETER M. KOGGE (IBM, Federal Systems Div., Owego, NY) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 236-245.
(AIAA PAPER 87-2818)

This paper addresses the characteristics that an embedded processing system must have to support AI functions for various avionics applications. The emphasis is on those kinds of functions that are unconventional in nature, computationally stressing, and of high value to future real-time avionics systems. The topics covered include a brief review of the major computational models for AI in use today, their appropriateness to several avionics AI applications, what their implementation means in terms of processor architectures, and how they might be supported in high performance avionics systems of the near future. Author

A88-12575#
AUTONOMOUS PROCESSING USING A BLACKBOARD CHIPSET
STEPHEN A. UCZEKAJ (Boeing Aereospace Co., Seattle, WA), ROBERT GRAHAM, DZIEM NGUYEN, CALVIN LING, THOMAS SKILLMAN (Boeing High Technology Center, Seattle, WA) et al. IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 358-362. refs
(AIAA PAPER 87-2855)

In the present evaluation of the capabilities of a 'blackboard' AI chipset that can accomplish the cooperative working of separate processes toward the solution of a problem in autonomous processing tasks, attention is given to the development of the chipset that will support the blackboard framework. Chipset support of the blackboard framework is by means of a blackboard control unit that allows opportunistic problem-solving to be undertaken among multiple clusters of processors dedicated to coarse-grain granularity in real-time embedded applications. The autonomous processing capabilities are required for military aircraft threat detection/avoidance and target location/identification. O.C.

A88-13109
ADVANCED COMPUTING FOR MANUFACTURING
ALBERT M. ERISMAN and KENNETH W. NEVES (Boeing Computer Services Co., Seattle, WA) Scientific American (ISSN 0036-8733), vol. 257, Oct. 1987, p. 163-169.

The use of supercomputers to help design aerodynamically efficient aircraft is discussed. The vector and parallel architecture of supercomputers that facilitates such applications is described. The development of software for computerized manufacturing applications is examined, and problems concerning the integration of user, graphics workstation, and supercomputer are addressed.
C.D.

N88-11165*# Pratt and Whitney Aircraft, East Hartford, Conn.
3-D INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS
E. S. TODD *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 239-243 Oct. 1985
(Contract NAS3-23697)
Avail: NTIS HC A19/MF A01 CSCL 09B

The objective is to produce a series of new computer codes that permit more accurate and efficient three dimensional inelastic structural analysis of combustor liners, turbine blades, and turbine vanes. Each code embodies a progression of mathematical models for increasingly comprehensive representaion of the geometrical features, loading conditions, and forms of nonlinear material response that distinguish these three groups of hot section components.
Author

N88-11166*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
COMPONENT SPECIFIC MODELING
R. L. MCKNIGHT and M. T. TIPTON *In* NASA. Lewis Research Center, Turbine Engine Hot Section Technology, 1985 p 245-257 Oct. 1985
(Contract NAS3-23687)
Avail: NTIS HC A19/MF A01 CSCL 09B

The objective is to develop and verify a series of interdisciplinary modeling and analysis techniques that have been specialized to address three specific hot section components. These techniques will incorporate data as well as theoretical methods from many diverse areas including cycle and performance analysis, heat transfer analysis, linear and nonlinear stress analysis, and mission analysis. The new methods developed will be integrated to provide an accurate, efficient, and unified approach to analyzing combustor burner liners, hollow air-cooled turbine blades, and air-colled turbine vanes. For these components, the methods developed will predict temperature, deformation, stress, and strain histories throughout a complete flight mission.
Author

N88-11382*# George Washington Univ., Washington, D.C. Dept. of Operations Research.
SOFTWARE RELIABILITY MODELS FOR FAULT-TOLERANT AVIONICS COMPUTERS AND RELATED TOPICS Final Report, 1 Jul. 1981 - 30 Jun. 1987
DOUGLAS R. MILLER 4 Nov. 1987 17 p
(Contract NAG1-179)
(NASA-CR-181440; NAS 1.26:181440) Avail: NTIS HC A03/MF A01 CSCL 09B

Software reliability research is briefly described. General research topics are reliability growth models, quality of software reliability prediction, the complete monotonicity property of reliability growth, conceptual modelling of software failure behavior, assurance of ultrahigh reliability, and analysis techniques for fault-tolerant systems.
Author

N88-11429*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
THE SPATIALLY NONUNIFORM CONVERGENCE OF THE NUMERICAL SOLUTION OF FLOWS
ARGYRIS G. PANARAS Nov. 1987 30 p
(NASA-TM-100037; A-88016; NAS 1.15:100037) Avail: NTIS HC A03/MF A01 CSCL 12A

The spatial distribution of the numerical disturbances that are generated during the numerical solution of a flow is examined. It is shown that the distribution of the disturbances is not uniform. In regions where the structure of a flow is simple, the magnitude of the generated disturbances is small and their decay is fast. However, in complex flow regions, as in separation and vortical areas, large magnitude disturbances appear and their decay may be very slow. The observed nonuniformity of the numerical disturbances makes possible the reduction of the calculation time by application of what may be called the partial-grid calculation technique, in which a major part of the calculation procedure is applied in selective subregions, where the velocity disturbances are large, and not within the whole grid. This technique is expected to prove beneficial in large-scale calculations such as the flow about complete aircraft configurations at high angle of attack. Also, it has been shown that if the Navier-Stokes equations are written in a generalized coordinate system, then in regions in which the grid is fine, such as near solid boundaries, the norms become infinitesimally small, because in these regions the Jacobian has very large values. Thus, the norms, unless they are unscaled by the Jacobians, reflect only the changes that happen at the outer boundaries of the computation domain, where the value of the Jacobian approaches unity, and not in the whole flow field.
Author

N88-11435*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
APPROACH TRAJECTORY PLANNING SYSTEM FOR MAXIMUM CONCEALMENT
DAVID N. WARNER, JR. Jul. 1986 17 p
(NASA-TM-88258; A-86264; NAS 1.15:88258) Avail: NTIS HC A03/MF A01 CSCL 12A

A computer-simulation study was undertaken to investigate a maximum concealment guidance technique (pop-up maneuver), which military aircraft may use to capture a glide path from masked, low-altitude flight typical of terrain following/terrain avoidance flight enroute. The guidance system applied to this problem is the Fuel Conservative Guidance System. Previous studies using this system have concentrated on the saving of fuel in basically conventional land and ship-based operations. Because this system is based on energy-management concepts, it also has direct application to the pop-up approach which exploits aircraft performance. Although the algorithm was initially designed to reduce fuel consumption, the commanded deceleration is at its upper limit during the pop-up and, therefore, is a good approximation of a minimum-time solution. Using the model of a powered-lift aircraft, the results of the study demonstrated that guidance commands generated by the system are well within the capability of an automatic flight-control system. Results for several initial approach conditions are presented.
Author

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PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A88-10047
AIRCRAFT ACOUSTICS I - EXTERIOR NOISE OF SUBSONIC PASSENGER AIRCRAFT AND HELICOPTERS [AVIATSIONNAIA AKUSTIKA. I - SHUM NA MESTNOSTI DOZVUKOVYKH PASSAZHIRSKIKH SAMOLETOV I VERTOLETOV]
ANATOLII GRIGOR'EVIC MUNIN, ED. Moscow, Izdatel'stvo Mashinostroenie, 1986, 248 p. In Russian. No individual items are abstracted in this volume.

Problems related to the effect of the exterior noise produced by subsonic aircraft and helicopters on the environment and man are examined. The principal sources of noise produced by aircraft and helicopters are identified, and the physical pattern of noise generation is examined. Various method of reducing the noise of aircraft and helicopters are discussed, and methods are presented for predicting the acoustic environment at airports with allowance for the size of the aircraft park and the dynamics of flight operations. V.L.

A88-10048
AIRCRAFT ACOUSTICS II - CABIN NOISE IN PASSENGER AIRCRAFT [AVIATSIONNAIA AKUSTIKA. II - SHUM V SALONAKH PASSAZHIRSKIKH SAMOLETOV]
ANATOLII GRIGOR'EVIC MUNIN Moscow, Izdatel'stvo Mashinostroenie, 1986, 264 p. In Russian. No individual items are abstracted in this volume.

Results of theoretical and experimental studies of cabin noise and noise on the fuselage of passenger aircraft are presented, and methods of noise reduction are discussed. The discussion covers the principal noise sources, such as the gas jet, compressor, turbulent boundary layer, propeller, engine vibration, and air conditioning system. Cabin noise reduction methods discussed include sound and vibration insulation and sound and vibration absorption. Finally, methods for calculating cabin noise are presented. V.L.

A88-12281*# Purdue Univ., West Lafayette, Ind.
PREDICTION OF SOUND FIELDS IN CAVITIES USING BOUNDARY-ELEMENT METHODS
R. J. BERNHARD, B. K. GARDNER, C. G. MOLLO (Purdue University, West Lafayette, IN), and C. R. KIPP (AT&T Bell Laboratories, Whippany, NJ) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1176-1183. Previously cited in issue 22, p. 3338, Accession no. A86-45484. refs
(Contract NAG1-58)

N88-10588# Air Force Occupational and Environmental Health Lab., Brooks AFB, Tex.
FIRST ARTICLE TEST NOISE SURVEY OF THE A/F32T-9 LARGE TURBO FAN ENGINE ENCLOSED NOISE SUPPRESSOR SYSTEM, SKY HARBOR IAP (INTERNATIONAL AIRPORT), PHOENIX, ARIZONA Final Report, for Period Ending Nov. 1986
JEFFERY C. JENKINS and TERRY M. FAIRMAN Jun. 1987 160 p
(AD-A183799; USAFOEHL-87-082EH0186FNA) Avail: NTIS HC A08/MF A01 CSCL 20A

The A/F32T-9 Large Turbofan Engine, Enclosed Noise Suppressor System (T-9 NSS) at Sky Harbor International Airport, Phoenix, Arizona was surveyed to determine noise levels at 100 meters. With an F101 engine operating at afterburner power the highest measured Overall Sound Level, A-Weighted (OASLA) was 88.7 dB(A). The measured OASLA values exceeded the 77 dB(A) criterion at all but five of the twenty-four sampling positions. GRA

N88-10589# Southampton Univ. (England). Inst. of Sound and Vibration Research.
ACTIVITIES REPORT OF THE INSTITUTE OF SOUND AND VIBRATION RESEARCH Annual Report, period ending Mar. 1987
1987 49 p
(ETN-87-90685) Avail: NTIS HC A03/MF A01

Research concerning fluid dynamics and acoustics; audiology and human effects; structures and machinery; and signal processing and control is summarized. Aircraft noise; underwater acoustics; silencers; biomechanics; noise measurement; hearing; structural dynamics; laser technology; automotive engineering; and active control are discussed. ESA

N88-10592*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
NOISE OF A MODEL HIGH SPEED COUNTERROTATION PROPELLER AT SIMULATED TAKEOFF/APPROACH CONDITIONS (F7/A7)
RICHARD P. WOODWARD 1987 25 p Presented at the 11th Aeroacoustics Conference, Sunnyvale, Calif., 19-21 oct. 1987: sponsored by AIAA
(NASA-TM-100206; E-3766; NAS 1.15:100206; AIAA-87-2657)
Avail: NTIS HC A03/MF A01 CSCL 20A

A high speed advanced counterrotation propeller, was tested in the NASA-Lewis 9 x 15 foot Anechoic Wind Tunnel at simulated takeoff/approach conditions of 0.2 Mach number. Acoustic measurements were taken with fixed floor microphones, an axially translating microphone probe, and with a polar microphone probe which was fixed to the propeller nacelle and could take both sideline and circumferential acoustic surveys. Aerodynamic measurements were also made to establish the propeller operating conditions. The propeller was run over a range of blade setting angles from 36.4/36.5 to 41.1/39.4 deg, tip speeds from 165 to 259 m/sec, rotor spacings from 1.56 to 3.63 based on forward rotor tip chord to aerodynamic separation, and angles of attack to + or - 16 deg. First order rotor alone tones showed highest directivity levels near the propeller plane, while interaction tone showed high levels throughout sideline directivity, especially toward the propeller rotation axis. Interaction tone levels were sensitive to propeller row spacing while rotor alone tones showed little spacing effect. There is a decreased noise level associated with higher propeller blade numbers for the same overall propeller thrust. Author

N88-10594 National Physical Lab., Teddington (England). Div. of Radiation Science and Acoustics.
NOISE LEVELS FROM PROPELLER-DRIVEN AIRCRAFT MEASURED AT GROUND LEVEL AND AT 1.2 M ABOVE THE GROUND
R. C. PAYNE Mar. 1987 63 p
(NPL-AC-110; ISSN-0143-7143; ETN-87-90931) Avail: Issuing Activity

Aircraft noise measurements using microphones close to the ground plane and at a height of 1.2 m showed substantial differences between measured A-weighted sound levels. The differences depend on ground cover, aircraft type, and flight maneuver. The ground-plane microphones produced A-weighted levels which closely approximate to pressure-doubled values. Two procedures for correcting A-weighted sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, were examined. In one procedure the noise spectrum was assumed to be represented by a series of 1/3-octave bands, in the other by a number of pure tones or discrete narrow-bands of noise. Neither correction procedure is wholly successful. It is concluded that, to avoid significant variations in measured A-weighted levels, noise measurements must be made using a ground-plane microphone. ESA

N88-10595# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
NOISE EMISSION OF CIVIL AND MILITARY AERO-ENGINES. SOURCES OF GENERATION AND MEASURES FOR ATTENUATION
H. GRIEB and K. HEINIG Sep. 1986 25 p Presented at the NATO Symposium on Aircraft Noise in the Modern Society, Mittenwald, West Germany, 22-25 Sep. 1986
(ETN-87-91021) Avail: NTIS HC A03/MF A01

It is shown that noise reduction on high bypass ratio turbofans for civil airliners is well established. The noise levels achieved meet the internationally agreed regulations (FAR 36). The same holds true for large military transport aircraft. Helicopter noise is caused essentially by the main and tail rotors. Noise reduction on afterburner and dry engines for combat and strike aircraft, which represent the major noise annoyance to the public, is very difficult because: high specific thrust is mandatory for aircraft performance and effectiveness; jet noise with and without afterburning is predominant; and the design of the reheat section and final (variable) nozzle in practice precludes the application of known concepts for jet noise attenuation in dry and reheated operation. ESA

N88-10608# NKF Engineering, Inc., Reston, Va.
FIBER OPTIC ENGINEERING SENSOR SYSTEM. PRELIMINARY PROGRAM MANAGEMENT PLAN, PHASE 3 REVISION
Jul. 1987 36 p
(Contract N00014-87-C-2032)
(AD-A183663; NKF-87103-003/03-REV) Avail: NTIS HC A03/MF A01 CSCL 17E

The principal objective of this program is to develop a Fiber Optic Engineering Sensor System (FOESS) including sensors, telemetry, and displays for applications such as damage control, system control (i.e., propulsion or steering) and intrusion defense systems for ship, aircraft and shore applications. This objective is being achieved by research and engineering effort conducted in three, originally four, contractually defined phases. GRA

N88-10610# British Aerospace Aircraft Group, Preston (England). Maths Services Dept.
THE DEVIATION OF LIGHT RAYS PASSING THROUGH A CURVED WINDSCREEN
S. WHITTLE 12 Jan. 1987 20 p
(BAE-MSC.115; ETN-87-90680) Avail: NTIS HC A03/MF A01

Formulas for the deviation of light rays passing through the windscreen of a fighter aircraft are obtained. The collimation of the head up display can then be altered so that the display does not appear further away than the ground. ESA

N88-11451*# *National Aeronautics and Space Administration.* Langley Research Center, Hampton, Va.
HELICOPTER MAIN-ROTOR SPEED EFFECTS ON FAR-FIELD ACOUSTIC LEVELS
ARNOLD W. MUELLER, OTIS S. CHILDRESS, and MARK HARDESTY (McDonnell-Douglas Helicopter Co., Mesa, Ariz.) Oct. 1987 20 p Prepared for presentation at the 114th Meeting of the Acoustical Society of America, Miami, Fla., 16-20 Nov. 1987
(NASA-TM-100512; NAS 1.15:100512) Avail: NTIS HC A03/MF A01 CSCL 20A

The design of a helicopter is based on an understanding of many parameters and their interactions. For example, in the design stage of a helicopter, the weight, engine, and rotor speed must be considered along with the rotor geometry when considering helicopter operations. However, the relationship between the noise radiated from the helicopter and these parameters is not well understood, with only limited model and full-scale test data to study. In general, these data have shown that reduced rotor speeds result in reduced far-field noise levels. This paper reviews the status of a recent helicopter noise research project designed to provide experimental flight data to be used to better understand helicopter rotor-speed effects on far-field acoustic levels. Preliminary results are presented relative to tests conducted with a McDonnell Douglas model 500E helicopter operating with the rotor speed as the control variable over the range of 103% of the main-rotor speed (NR) to 75% NR, and with the forward speed maintained at a constant value of 80 knots. Author

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SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

N88-10697# National Aerospace Lab., Amsterdam (Netherlands).
AEROSPACE RESEARCH AT THE NATIONAL AEROSPACE LABORATORY (NLR)
1987 40 p Original contains color illustrations
(ETN-87-90821) Avail: NTIS HC A03/MF A01

Research in fluid dynamics (wind tunnel tests, computational aerodynamics, unsteady aerodynamics, aeroacoustics, propulsion); flight (handling qualities, aircraft performance, flight tests, systems, flight simulation, certification, air traffic control, human factors engineering); aerospace structures and materials; satellite control; remote sensing; robotics; microgravity; and computing science is described. ESA

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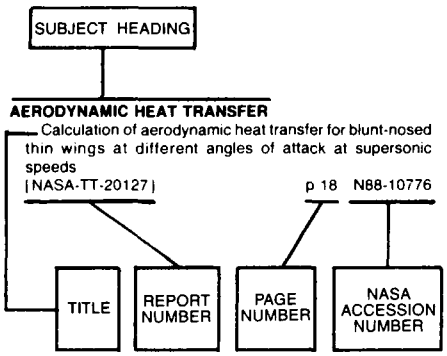
GENERAL

A88-12202
INVESTIGATIONS IN THE HISTORY AND THEORY OF DEVELOPMENT OF AEROSPACE SCIENCE AND TECHNOLOGY. NUMBER 5 [ISSLEDOVANIIA PO ISTORI I TEORII RAZVITIIA AVIATSIONNOI I RAKETNO-KOSMICHESKOI NAUKI I TEKHNIKI. NUMBER 5]
B. V. RAUSHENBAKH, ED. Moscow, Izdatel'stvo Nauka, 1986, 240 p. In Russian. No individual items are abstracted in this volume.

Several papers are presented concerning the history of aerospace science and technology. Papers are also presented on the development of unmanned winged flight vehicles, glider design, aircraft with rocket engines, and variable wing geometry. B.J.

Typical Subject Index Listing



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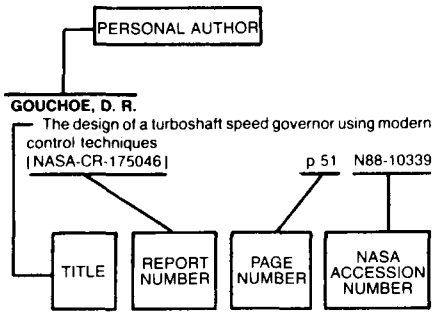

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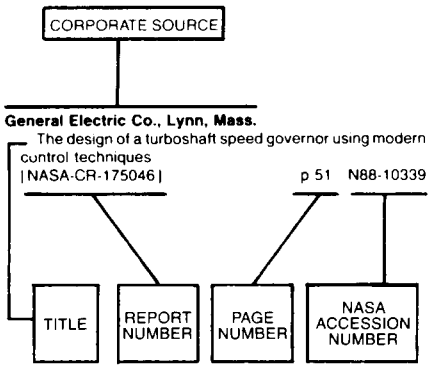

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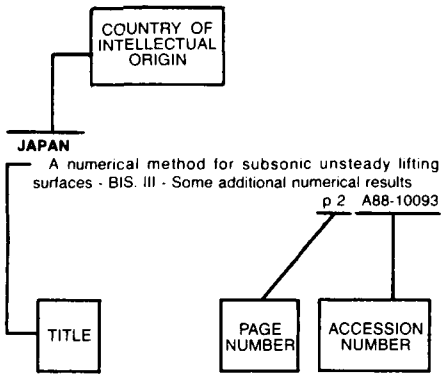

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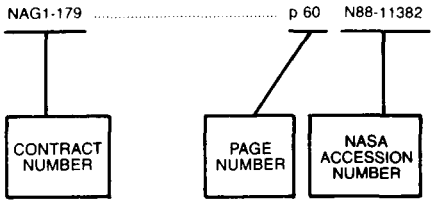

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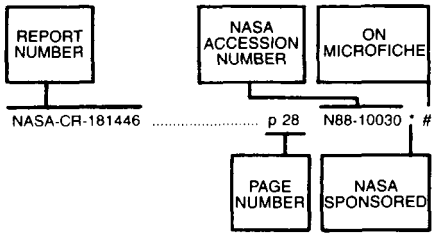

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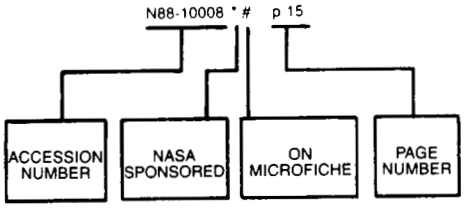

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